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EVERYDAY BIOLOGY

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General Preface

THE object of HODDER AND STOUGHTON'S PEOPLE'S LIBRARY is to supply in brief form simply written introductions to the study of History, Literature, Biography and Science; in some degree to satisfy that ever-increasing demand for knowledge which is one of the happiest characteristics of our time. The names of the authors of the first volumes of the Library are sufficient evidence of the fact that each subject will be dealt with authoritatively, while the authority will not be of the "dry-as-dust" order. Not only is it possible to have learning without tears, but it is also possible to make the acquiring of knowledge a thrilling and entertaining adventure. HODDER AND STOUGHTON'S PEOPLE'S LIBRARY will, it is hoped, supply this adventure.

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Preface

THE aim of this little book is to serve as an unconventional introduction to a biological way of thinking. It keeps close to matters of everyday experience and is content to suggest the biological consideration of these :—The moving and feeling creature, how it keeps agoing, how its behaviour is regulated, how it relates itself to the outer world, how it persists in its own line of being, how the past lives in the present and yet allows the new to emerge, the influence of habits and surroundings, the curve of the individual life, the length of life's tether, the shears of fate, how the creature grows old and how it may sometimes grow young. There is not the slightest attempt at comprehensive treatment; the purpose is simply to *illustrate* the use of the biological torch and to provoke further inquiry. Candidates reading for examinations in Biology will not find what they want in these pages, but it is possible that they may find something better.

It is a pleasure to thank the proprietors and editors of *John o' London's Weekly*, *The New Statesman*, *Time and Tide*, and *The Glasgow*

Herald, for their courtesy in allowing me to use as a basis for this book sundry articles which appeared in their papers.

J. A. T.

The University, Aberdeen,
Autumn, 1923

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Chapter I — The Emergence of Life

THIS is a perennial question to which men will return until they find an answer or lose the curious spirit. *How did living creatures begin to be?* We do not mean the plants and animals of to-day, but the simple primeval creatures ancestral to all. What was the origin of that subtle and elusive kind of activity that we call life? When we speak of *living* we mean, for the most part, action and reaction, give and take, between an animal (or a plant) and its surroundings. Living is a thrust and parry business between organism and environment. But Life? Life is a unique kind of activity; life is the organism's secret.

The first step that counts.—The Bishop told the witty French lady of the miracle of St. Denis, who, after he had been beheaded, walked a long distance around the walls of Paris with his head in his hands. "Yes, Seigneur," she said, "that *was* a case where it was only the first step that was difficult." (*Ce n'est que le premier pas qui coûte.*) This is an allegory. The age-long process of organic evolution is still miracle and mystery enough, using these words advisedly because scientific investigation has not as yet made more than a few evolution-

ary causalities *quite sure.* But the problem of the evolution of the living creature is probably less difficult than that of its origin. *Ce n'est que le premier pas qui coûte.* Once you have got a living creature started as a going concern, *then the scientific field is clear for experiments* and reasonable speculations as to the factors in evolution. But there is "a previous question." How did living creatures emerge—*as new syntheses*—in the inorganic world?

Suggested answers.—The first answer is not scientific but transcendental. It lays stress on the marvel and mystery of life, and holds that living creatures began in some way outside our scientific experience. As has been said, "protoplasm is a handful of dust that God enchants." But perhaps this might be said of everything, and however true it may be, it does not satisfy the inquisitive spirit. It is not antithetic to a scientific answer; it is in another language. The only objection to it is when it is used to foreclose inquiry. No one can object to saying "Ignoramus," but it is very premature to say "Ignorabimus."

The second answer is scientifically agnostic. It says frankly, "we do not know"; it doubts if we have sufficient data to allow us to put the question in the right way. It asks if we are sure that life ever began. For it may be that the secret of life is as old as energy or electricity, and we do not trouble ourselves over-much with the question of the origin of these fundamentals. This position is almost over-cautious, for it is never too soon to ask questions. The

danger is in being satisfied with a premature answer.

Germs borne from elsewhere.—The third answer is that backed by the names of Kelvin and Helmholtz and others, that minute living organisms may have come to the earth from elsewhere. They may have reached the earth in the cracks of a meteorite, or among cosmic dust, sinking gently as Richter supposed, or wafted by luminous vibrations as Arrhenius suggested. This ingenious theory shifts the responsibility of the problem off the earth, but leaves it quite unsolved. If simple living creatures reached the earth from elsewhere, what was their origin there? Perhaps the greatest difficulty in the way of Lord Kelvin's theory of meteor transport is to understand the survival of the germs of life when the meteor was passing through the intense cold of space and through the intense heat as it hurried through our atmosphere. On the other hand, the experiments of Berthelot have shown that simple forms of life can endure extremes of heat and cold without being fatally injured. Their activities may be suspended or slowed down to a vanishing point, but they can be resumed when the conditions are appropriate. It is molecular disintegration that is fatal.

The evolutionist answer.—The fourth answer is that living creatures of a very simple sort may have evolved on the earth's surface from not-living material, *e.g.*, from some colloidal carbonaceous slime activated by ferments. No case of such an occurrence is known, but we must not make a dogma of the fact of experience:

omne vivum e vivo, all life from life. This " spontaneous generation " idea fits in well with the general trend of evolutionist thinking. It is in line with what seems to have been one of the fundamental tendencies of the world—to complexify. Electrons and protons form atoms; atoms build up molecules; molecules combine into larger molecules; and so the complexifying process runs. The theory is also in harmony with the achievements of the synthetic chemist, who can artificially build up such carbon-compounds as grape-sugar, oxalic acid, indigo, and caffeine. In recent years there has been an approach to the artificial synthesis of proteins—those complex carbon-compounds, like albumen, which form a universal and essential part of the physical basis of life. It must be noted, however, that the procedure by which the modern chemical magician builds up a complex organic substance may not throw any direct light on the way in which that substance is built up in Nature. The chemist can build up oxalic acid, but his method is not that followed in the laboratory of the wood-sorrel's leaves. And if the living was built up long ago from the not-living, the difficulty must be faced of discovering what processes in Nature can be thought of as taking the place of the rational chemist who picks and chooses and combines. So we turn to some concrete suggestions.

Spontaneous generation.—One of the concrete suggestions starts from a compound of carbon and nitrogen called cyanogen (CN). This and its compounds may arise in an incandescent

heat, and may thus have been formed while the earth was still aglow. The cyanogen compounds are unstable and might readily form linkages with other compounds, especially when water began to be precipitated on the cooling crust of the earth. This is one of the possible pathways by which living matter may have evolved.

Another hint has been found in the fact that when an electric discharge is passed through a mixture of carbon-dioxide and water-vapour the two may combine to form a simple carbohydrate, *e. g.*, formaldehyde. It may occur when lightning flashes through the atmosphere above a volcano, or sometimes, they say, more slowly under the influence of continued sunlight. In recent days it has been reported that the prolonged exposure of carbon-dioxide and water to certain kinds of light does actually result in the formation of formaldehyde just as in a green leaf. From ammonia or ammonium salts the simple carbohydrate might capture nitrogen and form amino-acids, which have been called the "basic substances" of life. By further linkages and by incorporating minute quantities of salts, the amino-acids might give rise to proteins which are the main constituents of living matter. Perhaps the finishing touch to the carbonaceous nitrogenous jelly was given by the addition of a "catalyser," such as some mineral salt. A catalyser is a substance which starts a reaction between the constituents of a mixture, and keeps that reaction agoing without itself apparently sharing in the process.

There are other hints—all of them "peradventures"; but our point at present is that the theory of the evolution of the living from the not-living is no longer altogether in the air. Its concreteness will grow.

Cautions.—But an open-minded expectancy does not lead us to abandon scientific caution, or to regard in any easy-going way what must be admitted to be one of the most difficult of problems. There are not in living matter any but common chemical elements—notably the Big Four, carbon, hydrogen, oxygen, and nitrogen, which were readily available in large quantities (as carbon-dioxide, water, and nitrogen) on or near the surface of the cooling earth. On the other hand, we do not know of living matter in Nature except in living organisms, and a living organism is more than a blob of living matter. It is an individual that is ever changing and yet for a while remaining the same; it grows and multiplies; it is an agent that does things and enregisters its experience. It is something big and unique that we try to account for in our speculations on the origin of organisms. When we think of the insignia of livingness we cannot but feel that the natural evolution of living creatures from non-living raw materials is not to be spoken of glibly.

Continuity in evolution.—And yet, if the synthetic chemists should go on as they have been doing, if the artificial up-building of proteins should be effected, and if facts should accumulate in favour of the hypothesis that organisms evolved long ago from the inorganic, this would

not greatly affect our general outlook on the world of life, for origins do not alter values. But it would increase our appreciation of what used to be libelled "inert." If the dust of the earth did once upon a time naturally give rise to simple living creatures, if they are in a very real sense born of the earth and the sunshine, then the whole world becomes continuous and vital, and all the inorganic groaning and travailing becomes more intelligible.

What of mind?—No one doubts that the elephant is very intelligent, that it has an inner life of thinking, feeling, and willing. There is a real aspect of the creature that we call for short its "mind." When we pass from the elephant to the amœba, the evidence of mind is not so clear; and yet, if we hold to the idea of continuity in evolution, we must credit the amœba with the rudiments of mentality. Similarly with the infant as compared with the man, we believe in the reality of the two aspects—physiological and psychological—throughout. Push the argument farther back, and if the first living creatures evolved from the not-living, there must be below the confines of life the rudiments or potentiality of a mental aspect that sleeps in the plant (with flowers like happy dreams!), and wakes more and more in the animal scale of being. For we hold to the Aristotelian idea that there is nothing in the end which was not also in kind in the beginning.

LIVING creatures have a secret which the inanimate does not share. But what the secret precisely is, no one has discovered. This does not prevent us pressing home the question: What is distinctive about that particular kind of activity which we call living?

What may be called the Positivist answer to the question: What is Life? is that living implies a twofold relation between Organism and Environment. At one moment surrounding influences play upon the living creature, warming it or chilling it, illumining it or shading it, stimulating it or dulling it, and so forth. At another moment the living creature acts on its surroundings, displacing them, changing them, using them, eating them.

Persistence in spite of change.—Along with the influence of the environment we may include the influence of food, for what is food but part of the environment which the organism takes inside itself. In the case of green plants that feed on air and soil-water, it is plainly very difficult to draw a line between environment and food. Similarly for a parasite like a tape-worm floating in the half-digested food of its host's alimentary canal,

or a Sleeping Sickness animal (a Trypanosome) rushing about in the human blood. The environment, biologically regarded, includes the food.

Huxley compared the living creature to the famous whirlpool three miles below the Falls of Niagara :—

"The whirlpool is permanent, but the particles of water which constitute it are incessantly changing. Those which enter it, on the one side, are whirled around and temporarily constitute a part of its individuality; and as they leave it on the other side, their places are made good by new-comers. . . . Seen from a mile off, it (the heaped-up wave below the Falls) would appear to be a stationary hillock of water. Viewed closely, it is a typical expression of the conflicting impulses generated by a swift rush of material particles. Now, with all our appliances, we cannot get within a good many miles, so to speak, of the crayfish [the animal]. If we could, we should see that it was nothing but the constant form of a similar turmoil of material molecules which are constantly flowing into the animal on the one side and streaming out on the other."

This fine passage expresses the fundamental fact that the living creature retains its integrity in spite of ceaseless change. It persists like the vortex ring in the quiet air *in virtue of* its ceaseless change.

Running down and winding up.—In all living creatures there is a more or less continuous breaking down and building up of carbon-compounds, especially proteins like white of egg. All living involves the metabolism of proteins; and

the essential chemical processes may be grouped as up-building or anabolic and down-breaking or katabolic. Food is taken in and altered until it is incorporated in the living matter to replace the proteins, sugars, fats, and other carbon-compounds that have been broken down or used-up. But the essential feature is that for prolonged periods, it may be a thousand minutes or a thousand years, the living creature balances accounts. It is a going concern; it is a self-stoking and self-repairing engine.

Capitalisation.—There is intense activity of a very simple kind when the potassium ball fizzes about on the surface of the basin of water; but there is much more intense and more complex activity in the Whirligig Beetle that swims swiftly to and fro, up and down, in the pool. But the potassium ball soon flares all its activity away, while the beetle retains its integrity and lasts. It may be said, however, that this is only a difference in time, for the beetle eventually dies. Yet this is to miss the point. The peculiarity is that for certain periods there are in the living creature processes of winding-up which more than compensate for the processes of running-down. A primitive living creature was not worthy of the name until it could more than keep agoing for a certain time. Perhaps it was only a creature of a day, which died in the chill of its first night, but the point is that during its short life it was not like a glorified potassium ball or a clock running down. It was making ends meet.

No living creature can produce energy; it can only change it from one form to another. The

green plant changes the energy of the sunlight into chemical energy; the animal changes the chemical energy of its food into locomotion and heat. A living creature, like an engine, is an energy-transformer. But it is also an accumulator; it can absorb energy acceleratively. Its secret is capitalisation.

Organism more than mechanism.—The more heat energy is put into an iron bar, the more difficult it becomes to put in more, and the more readily does some of the heat radiate out. But it is different with the living creature. Professor Joly has put it tersely :—

"The transfer of energy into any inanimate material system is attended by effects retardative to the transfer and conducive to dissipation. The transfer of energy into any animate system is attended by effects conducive to the transfer, and retardative of dissipation. . . . The animate system is aggressive on the energy available to it, spends it with economy, and invests it with interest, till death finally deprives it of all."

Even the dying may be due rather to the wear and tear of the furnishings of the living laboratory (the cell) than to any intrinsic impairing of the powers of the living matter itself. On what this peculiar property of the living creature depends, we do not precisely know. There is *a complex chemical firm* in every living cell; the living matter occurs in *a colloid state* which has remarkable properties as regards energy; and there is the capacity for utilising the environment in an active way as a source of energy—feeding in the broadest

sense of the term. But the distinctive criterion of the living creature is this, that in a world where all the clocks, so to speak, are running down, it is able to counteract its running-down by also winding itself up. Living means a metabolism of proteins and other complex substances, but this goes on in such a way that the organism retains its integrity for days or years or centuries. Moreover, what is retained is something quite *specific*—a chemical individuality, a particular microscopic and ultra-microscopic architecture. The organism is itself and no other.

Everyday miracles.—It is very useful, for certain purposes, to compare a living body to an engine, but the comparison breaks down badly when we come to the everyday miracles of growing, multiplying, and developing. We drop a minute crystal of alum into a saturated solution of alum, and we may watch it growing. But it can only grow at the expense of material the same as itself. Whereas the grass grows at the expense of air and soil-water, and the foal grows at the expense of the grass. It is impossible to draw a line between growing and multiplying, for the liberation of a bud or the process of dividing into two means little more than discontinuous growth. If the lower third of a freshwater Hydra be cut off, the anterior end will re-grow what has been lost. But the cut-off portion will also grow a new Hydra.

We do not hear of this sort of thing in the not-living world, except to a slight extent among crystals. When an amœba becomes two amœbæ by dividing there is a more difficult problem than

the origin of a double star. One of the commonest events of the country is the minting and coining of the chicken out of the egg—out of a minute clear drop lying on the top of the yolk; and this condensation of intricate individuality into a simple, in most cases microscopic, and the emergence of obvious complexity out of this apparent simplicity must be regarded as absolutely distinctive of the Living.

Behaviour, registration, change.—Perhaps, after all, we come nearest the heart of the matter when we think of the living creature's power of doing things, of enregistering its experience and experiments, and of giving origin to the new. If a match is applied to a barrel of gunpowder, there is an answer-back; but it is self-destructive. Whereas the organism's reaction to a stimulus tends to be self-preservative. Even to a poison that proves fatal, or to an intruding microbe that kills, the organism often answers-back effectively. It is not less characteristic—and this begins as low down as the amœba—that it can link actions in a chain so that the result is behaviour—purposelike and, in the higher reaches, purposive and finally purposeful behaviour.

The living creature profits by its experiences. The past lives on in the organism in a manner that we have only dim analogues of in the not-living world. Almost as distinctive, again, is the emergence of the new, whether that be called a genius, or a crank, or a freak, or a sport, or a mutation, or a variation. There is in living creatures a ceaseless fountain of change—more copious in some than in others, of course. Finally,

since the mental activity of living creatures becomes indisputable in the higher forms, we can hardly resist the conclusion that this aspect of reality is struggling for expression throughout. Perhaps this is the central secret of life.

Chapter III Life in Motion

BACON defined one of the ends of science as the discernment of the secret motions of things, and everyone knows that the continuance of our life from day to day depends on vital movements. Some of these, like the breathing movements, we can actually see; others, like the beating of the heart, we can feel. But others, like the ceaseless lashing of the cilia lining our windpipe, are quite microscopic, and the most important of all, namely, the dance of molecules involved in all vital changes (or metabolism) are ultra-microscopic. It is interesting to remember, however, that the quivering movements of granules in a fluid medium, such as living matter affords, are due to the microscopically visible particles being jostled by the invisible dancing molecules. But what we wish to discuss are the gross movements of living creatures rather than the fundamental secret motions—always remembering, of course, that the former depend on the latter.

Kinds of animal locomotion.—In his fascinating *Animal Life*, Professor F. W. Gamble points out (we are quoting from memory) that there are among animals four main methods of locomotion, which may be readily kept in mind if we think

of a man in a boat on a quiet reach of the river. First, he may take a boat-hook, and fastening it to the roots of the willows he may pull the boat against the gentle current. This pulling method is illustrated when a leech fastens its anterior sucker and pulls its body forward, or when a starfish hauls itself up or along a rock by contracting several scores of suctorial tube-feet which it had attached.

Secondly, the man may take a pole and push with it against the bed of the stream. This punting method is very general among land animals which use their limbs as levers with which to press against the ground. A beetle punts along on its six legs, using them in subtle alternation. We do the same as bipeds, using about three hundred muscles between pressing on the ground with our left foot and doing the same, half a second later, with our right. As the immortal Monsieur Jourdain did not know that he had been talking prose all his life, so many of us may have been unaware that we punted along the ground when we took a walk.

Thirdly, the man in the boat may take an oar, and, going to the stern of the boat, sweep out big masses of water alternately to either side. This familiar sculling method is clearly illustrated by most fishes. They grip masses of water with their very muscular posterior body and jerk these forcibly away, first to one side and then to the other. Similarly, the whale's tail forms a powerful propeller—but it is a propeller that does not go round. The beaver's tail is also used for sculling, and an interesting case is that of sundry

sea-snakes, whose tail, or even more than the tail, is flattened from side to side, thus giving the lithe creatures a good grip of the water as they swim.

In the fourth place, the man in the boat may sit down and row with the two oars. We see this rowing in the insect known as the water boatman, which has two of its legs turned into long blades, in the aquatic birds that swim with their feet whether webbed or unwebbed, or in many a swimming mammal which strikes the water with its fore-limbs, or with fore and hind limbs together. The flightless penguin uses its flipper-like wings as oars, and the diving petrel swims with its wings under water, and actually emerges *flying* into the air. In the common dipper or water-ouzel of our streams there is also an interesting use of the wings under water. Such instances prepare us for the conclusion that flying, whether of bird or insect, bat or ancient dragon, is comparable to rowing in the air. Thus, following Professor Gamble's idea, we compare the four chief kinds of animal locomotion to pulling with a boat-hook, punting with a pole, sculling from the stern, and rowing with oars.

Strange modes of locomotion.—One is prepared to find difficult and curious cases. The jellyfish narrows the circumference of its disc and forces the water out from the diminished concavity, which is comparable, perhaps, to what might be called median sculling. The same term may be applied to the more intricate procedure of the cuttlefish. It fills its spacious mantle-cavity with water, buttons up the aperture by which the water entered, forcibly contracts the mantle-cavity,

and drives the water out by a narrow funnel. The force of the outgushing water drives the cuttlefish onwards, but in some cases there are also muscular fins with an undulatory motion. Not very far from this is the beautiful swimming of some scallops and of the bivalve called Lima, for the water is driven out forcibly from the mantle-cavity by the rapid approximation of the two shell-valves and of the paired folds of skin that form the shell-making mantle.

A sea-urchin climbs on the sea-shore rocks by means of its suctorial tube-feet; it is sometimes helped by the punting action of its numerous spines; but on a flat surface of caked mud it may show a quite unique method—it hobbles along on the tips of its teeth. Projecting from the mouth, which is always next the substratum, there are the tips of the five teeth of "Aristotle's lantern"—an elaborate chewing apparatus. The lantern is swayed from side to side by powerful muscles, and the five teeth with their projecting tips serve as levers by means of which the sea-urchin tumbles from one position of equilibrium to another, and gets slowly onwards. In most of the brittle-stars, first cousins of the starfishes, the tube-feet are too small to be used in locomotion, and what happens is a curious wriggling with the five very gymnastic arms which press against the substratum. If the brittle-star is picked off the sand and thrown into the water it may continue its wriggling, and the five punting poles become five oars.

The serpent on the rock.—The ordinary gliding of a snake may also be called multiple punting.

Attached to the strong ventral scales there are skin-muscles, the contraction of which raises the posterior margins, so that they catch on roughnesses on the ground. But the lower end of each of the very mobile ribs is fastened to a scale, and when the rib is pulled backwards by other muscles the body is pushed forward against the substratum which the scales grip. There is an alternation of scale-raising and rib-pulling, and while one region of the body is showing the former an adjacent region is showing the latter. Ruskin spoke of the snake "rowing on the ground with every rib for an oar," and "biting the dust with the ridges of its body," but as the movement depends on pressing against a firm substratum we prefer to think of it as "punting." A quick jerk or dart forwards on the snake's part is a different kind of movement, due to a sudden straightening of the sinuosities of its body.

Mystery of movement.—It is at once humiliating and stimulating that we understand so little of the true inwardness of animal locomotion. This may be illustrated by reference to the movements of the amœba, which is generally regarded as one of the simplest animals. It "glides" along, "flows" along, "rolls" along (see various text-books on zoology), and yet we do not understand how it progresses in its orderly, wavy path. Fundamental probably is a streaming movement of the living matter—a movement which has been compared to that of a caterpillar-wheel or "tank." Particles are seen travelling along the upper surface in the direction in which the amœba is moving; they disappear over the front and

reappear at the hind end. It almost looks as if the device of the "tank" had been anticipated by the amœba. But associated with the streaming movement of the living matter, there are changes of surface tension in the outermost zone of the little animal, and perhaps some gripping of the substratum. But we do not as yet understand the locomotion of the amœba.

Similarly, among the multicellular animals that *move about by means of muscles, whether by* pulling or punting, sculling or rowing, there is again a mystery of movement. For in the first chapter of muscular contraction, when each living thread or fibre of flesh becomes shorter and broader and does work, there is no combustion, no using up of oxygen, no formation of carbon-dioxide, no evolution of heat, only a dislocation of molecules of lactic acid from their association with the muscle substance. It seems like a physical change, comparable to the uncoiling of a released spring. In the second chapter, no doubt, there is an oxidation of a carbohydrate, with production of carbon-dioxide and heat, and the energy is used to reinstate the lactic acid molecules in their place in the muscle-substance. Our point is that the essential process of contraction remains as yet very mysterious, like the streaming of the protoplasm in the amœba and many other unicellular organisms.

The eagle in the air.—Once more, when we face the highest form of locomotion, which we take to be the "sailing" of the albatross and the vulture, must we not confess that it remains "too wonderful for us"? Without apparent

strokes of its wings, for half an hour at a time, the albatross describes majestic ellipses round the ship. It sails with the wind, apparently gaining rather than losing in velocity; it tilts its body and turns against the wind, losing in velocity, but, it may be, gaining in height; then it turns again, and so *da capo*. Similarly, the vulture describes its great spirals in the sky. There are men who profess to understand the sailing of birds like the albatross and vulture, but they seem to us to succeed in keeping their secret. We are not suggesting that there is anything magical; the bird is probably changing energy of position into energy of movement alternately till it re-acquires momentum by powerful strokes of its wings; it is perhaps taking advantage of currents of unequal velocity in the air; and the pressure of the breeze against the complex under-surface of the wing must have complicated results. No doubt the wonder of "sailing" will be cleared up, though it may remain, because of its difficulty, inexplicable to all but mathematicians. Our point is simply that whether we take the amœba rolling along, or our own everyday saunter, or the way of the vulture in the air, life in motion is a fact not to be spoken of lightly.

We owe much here to Sir Arthur Keith, whose *Engines of the Human Body* is probably the most interesting plain account of man's structure that has ever been written. Its central idea is the comparison of the working of the human body with the working of an engine.

The living motor.—Whether we ascend a hill road on a motor bicycle or on foot, we get to the top by mechanical work, the energy for which is supplied by the internal-combustion engine in the first case, by our muscles in the second. But while " a metal engine exerts its power by pushing the crank-pin, and has therefore a rigid cylinder and a rigid piston-rod, flesh engines exert their power by pulling, and changing their shape all the time; they have flexible piston-rods which we call tendons or sinews." A muscle is a " pull " engine; a motor bicycle or any similar contrivance is a " push " engine.

Walking.—When we are walking at the rate of four miles an hour, only half a second elapses from the time the heel is raised until the limb is swung forward and the foot is again planted on the ground. " Yet in that half-second fifty-four engines have been started and stopped,

speeded up and slowed down a countless number of times." When our left leg swings forward, the whole weight of our body is "supported on the round, slippery, and ball-shaped head of the right thigh bone; it is balanced there by all the muscles which surround the hip-joint, some fifteen in number, being set into motion and working against each other." And if the body sways the least bit off the plumb, the balancing muscles of the stationary limb counteract this, and this regulation takes place not only at the hip joint, but at the knee, and the ankle, and the arch of the foot. Moreover, there are 144 muscles attached to the vertebræ which give our backbone poise, and keep it from swaying unduly backwards or forwards, to one side or other, as we move. Indeed, there are about three hundred muscles concerned when we walk. "With every step—every half-second—some three hundred engines have been started, regulated, and stopped, and each has done its allotted task in helping the body forward." So we get a glimpse of the marvel of functional correlation. We cannot help being amazed that we have been doing such a difficult thing as walking with so much success for so many years!

The biceps muscle in the arm of a working man has over half a million fibres, each a microscopic engine-cylinder, comparable to the cylinder of a motor cycle. In each case there is the circulation of a combustion mixture, in both engine and muscle there is production of heat, in both there are contrivances like sparking plugs, in both there are the usual waste products of combustion—water

and carbon-dioxide. In the motor cycle the space within the cylinder is lengthened when an effective stroke is made, in the muscle the cylinder itself becomes shorter and wider. In the engine the oxidation of the fuel supplies the energy that makes the wheels go round. As we have already mentioned, the oxidation-process in the muscle is secondary to the actual contraction. The oxidation is really involved in a restoration of the muscle to the state that makes another contraction possible. As Sir W. M. Bayliss puts it: "The muscular system is analogous to that of a gas engine used to compress air into a reservoir, from which it is taken to drive, by its pressure, various machines and tools. The energy of the oxidation of the fuel is not used from the engine directly."

Muscles work in pairs.—The muscles work in opposing pairs, and when one goes into action a message travels to the brain so that the opponent muscle yields just to the right extent. They work like *reciprocal engines.* "When we take even a single step we set three hundred engines in motion, we set each going at the right instant; and from each of the three hundred messages are streaming into the brain and an equally great number are being despatched outwards from automatic control centres." We are fearfully and wonderfully made. And our engines, whose secret still eludes the physiologist, have other merits—they work so very smoothly, with so little noise; they always have their "steam up," ready to start work at an instant's notice; some of them never stop working, others are

able to rest; their standard of efficiency—the ratio of work done to fuel supplied—is about 25 per cent., whereas the best engine man has yet made does not turn more than 20 per cent. of the energy of fuel into effective work. Then they are self-repairing engines, requiring no looking after, *except* exercise. Fine as our muscles are, they are surpassed by those of many of the lower animals. It takes our breath away to find that a buzzing fly is contracting its wing-muscles over two hundred times in a second!

Levers of the body.—In a motor cycle the levers are of the complex wheel type; in our body they are ordinary levers, but living. The skull, whose relation to the backbone is a triumph of engineering, is a lever of the first order; the foot illustrates a lever of the second order; the lever formed by the forearm and hand, with the elbow as fulcrum, is of the third order. But this suggests too great simplicity. "What should we think of a metal engine which could reverse its action so that it could act through its piston-rod at one time and through its cylinder at another? Yet that is what a great number of the muscular engines of the human machine do every day." And the levers are living—the inside of a bone being occupied by microscopic units, the bone-corpuscles, working like the bees in a hive. About two millions of them are at work in the construction of the thigh-bone of a baby, and by the time the task is completed there is an army of 150 millions. "Nor is this army demobilised when growth is over; it is maintained as a standing army to look after the works and to effect repairs."

The rest of the engine.—From levers we naturally pass to the lubricating system, and there is a beautifully adapted arrangement whereby cartilage-builders make good the wear of the joint surface, and when their working days are over are dissolved to form a lubricant. But the muscular engines require stoking, the masons in the bones and the lubricators at the joints must have their stores constantly replenished, and that brings us to the heart—the pump of the body. By means of the capillaries which permeate everywhere a combustion mixture (oxygen and blood sugar) is brought to the muscle cylinders and the effete products are carried away.

The motor cycle has its respiratory chamber, into which air is drawn and from which air is forced out. Similarly, our chest is really a pair of bellows; there is a wind-pipe or air-pipe; there is a nose or nozzle; there are the air-chambers within the lungs where the red blood discs pick up their loads of oxygen. The engines which work the respiratory levers, and the levers themselves are built in to form the side and front walls of our thoracic bellows, and the floor or diaphragm is built in a very original way so as to act as a piston.

To follow out the comparison between the human body and an engine is beyond our scope here, but we strongly advise the reader to master Sir Arthur Keith's book from which we have quoted. It is necessary to think of the way in which the production and the escape of heat are regulated, so that the mass of the body is maintained, year in, year out, at a temperature

between 98° and 99° F.; of the workshops and laboratories where food is turned into fuel for the tissues; of the transport system from the mouth to the stomach, and its "touch-button" adjustments which allow of onward passage; of the biggest and busiest factory in the body, namely, the tube-like corridor of the small intestine which stretches for 20 feet or so; of the great chemical laboratory and storehouse which we call the liver; of the large intestine—a threatened factory which under modern conditions of diet is called upon to perform duties for which it was never intended, which must, therefore, be humoured and controlled in turn.

A motor cycle has a co-ordinating or timing system, consisting of a series of revolving toothed wheels set so as to be turned by the crank-shaft at fixed rates, but the time-gearing of the human body is very different. Sir Arthur Keith wisely drops his comparison with an engine and speaks rather of an army. "Our bodies are made up of billions of microscopic living units, each unit having an independent activity, and yet an activity which has to be co-ordinated with the work done by neighbouring units." The brain and spinal cord form the G.H.Q., the nerves a telegraphic system. There is also a postal system by which "key-missives" or hormones are despatched from organs of internal secretion and carried by the blood to tissues which they activate or control. The molecules of the hormone called secretin, a missive from the part of the food-canal just below the stomach which stimulates the pancreas to secrete digestive juice, "may be

regarded as ultra-microscopic Yale keys sent out to search for the locks of letter-boxes which they can fit and enter. They fit and can enter only the letter-boxes of the pancreatic molecules, *and hence they must circulate round the body until they automatically find their destination.* What is still more wonderful in this system is that the letter-boxes, or we may call them locks, have a positive attraction for the key-missives which are destined for them."

The master-contrivance in the body is the brain, with its millions of microscopic living "operatives" and its millions of delicate living wires. "To find any system which is comparable to that represented by the human brain, spinal cord, and nerves, we have to study the great machines [but why machines?], which are composed of living human units and make up the nations which lead in the van of civilisation." The fact is that the comparison of the body to an engine breaks down, and that the comparison of the body to an army or even a nation becomes strained. The unified regulation of the living creature remains something that we cannot at present at least explain in terms of anything else.

Chapter V *Food-Getting and Food-Using*

EVERYONE sees clearly that animals may get their food by hunting, or by fishing, or by gleaning, or by any one of half a dozen other ways; but there is a deeper and even more interesting question concerning the more fundamentally different ways of food-getting. We wish to show that there are at least ten of these ways, used by different types of creatures, which deserve to be arranged in some rational order.

Feeding like green plants.—Green plants are able to use part of the energy of sunlight, when it shines through a screen of green pigment or chlorophyll, to start the process of building up sugar and other carbon compounds from the raw materials furnished by air, water, and salts, especially from carbon-dioxide and water. Now, there are a few green animals, such as a green bell-animalcule, and some active swimmers called Euglenids, which have got chlorophyll of their own, and are able to feed like green plants. It is highly probable that one of the earliest forms of animal life was a flagellate unit able to fend for itself in the primeval sea.

Plants as Partners.—Most green animals, such as a green amœba, the green fresh-water

sponge, the green fresh-water Hydra, the green sea-anemone, the green corals, and the little green worm called Convoluta, are green not in their own right, but because they have minute green algæ living as partners within them. The partner plants are able to use carbon-dioxide and nitrogenous waste made by the animal that carries them, and the animal profits by oxygen given off by its partners during daylight and by the sugar they then make. At the worst the animal can digest its partners.

This is what is known as symbiosis, and it is very well illustrated by the beautiful radiolarians that float in uncountable numbers in the open sea. They are almost invariably provided with partner "yellow-cells," simple algæ which have formed a mutual benefit society with the radiolarian.

The vegetarians.—It was a tremendous event in the history of the world when primitive animals turned upon primitive plants and devoured them. Plants manufacture explosives; vegetarian animals seize them and use them to do work and mischief. Plants build up wealth from simple sources, such as air, water, and salts; vegetarian animals seize the plant's savings and spend them. Cows eating grass and sea-slugs browsing on the tangle serve to illustrate vegetarians of high and low degree.

The carnivores.—But it was another great event in the history of the world when primitive animals turned upon primitive animals, thus getting, on the whole, richer and more condensed food, with more proteins. Dr. Erasmus Darwin,

Charles Darwin's grandfather, said that he preferred to take his vegetable food in the form of beef and mutton, for it was more digestible. This was his jocular way of expressing the fact that all flesh is grass; the material of grass is reincarnated at a higher level—as flesh.

In the meadows of the sea.—The sedentary sponge lashes gallons of water through its body in the course of a day. It has really to work hard for its food, though it does not move about. It lives on minute creatures that form the living stock of the sea-soup. The same is true of fixed animals, such as oysters, sea-squirts, barnacles, acorn-shells, and of free but not very energetic animals like lancelets. In the open sea, down to a depth of 100 fathoms, there are floating sea-meadows of animalcules, some so small that they go through the microscopic meshes in the finest silk-cloth used in tow-netting, and these form the food of many active animals of the open sea. Some are of the plant persuasion, others of the animal persuasion, and others betwixt and between.

Eaters-up of fragments.—After a stormy night in the beginning of summer we realise what a lot of wastage there is on land. The ground is strewn with bud-scales, stipules, young leaves, and pieces of flowers. There are many vegetarian insects which delight in such fragments, and there are others that have a feast when there is a shower of pollen.

The same is true in shallow water round the coasts ; there is a vast amount of débris, consisting of fragments broken off from seaweeds and from the flowering plant called sea-grass. Around the

coast of Denmark the yield of sea-grass is four times the weight of the hay on the Danish fields, and its minute fragments form a very important part of the food-supply in shore-waters and out to considerable depths. This is the "sea-dust."

Feeding on decay.—Many moulds and other fungus plants feed on the decaying parts of plants and animals. Many small threadworms do the same. The fisherman's lobworm fills its food-canal with sand for the sake of the decaying fragments which it contains. The sea-cucumber plunges one feathery tentacle after another into the mud, gets it covered with sand and organic particles, and then plunges it into its mouth—a quaint way of feeding. Those animals that feed on decay keep the earth and the waters under the earth clean and sweet. But it must be remembered that the decaying matter is first prepared by the agents of all rotting—the ever-present bacteria.

Crumbs from the table.—When two animals live together as partners, helpful to each other, we call them "commensals," which means eating at the same table, just as companion means eating the same bread. Many a hermit crab has on the back of its borrowed shell a partner sea-anemone, which feeds on the crumbs that float up from the crustacean's well-spread table.

Life in a food-canal.—A great many animals live in the food-canal of other animals, and depend on the digested food of their host. Tapeworms and threadworms are good examples. In the case of tapeworms there is neither mouth nor food-canal, so the digested food of the host must

simply enter through the skin of the worm. This is interesting, because it means that the tapeworm is feeding altogether on fluid food, which is not common among animals. Even if we think of the food of blood-suckers, like the leech or the flea, we have not to deal with wholly fluid food, for blood is full of blood-cells that are not exactly fluid. Many plant-suckers, like green-flies, live on the fluid juices of plants. Parasites, such as tapeworms, feed on the food of their host, with whom they have established a sort of live-and-let-live compromise.

It is not in the interest of the parasite to kill its host, for that is killing the goose that lays the golden eggs. The ichneumon fly lays her eggs in a caterpillar, and the grubs devour the caterpillar, but we should not call these typical parasites. They are more like ravenous wild beasts which devour their prey from within instead of from without, and more slowly than quickly.

The parasite.—We started with an entirely independent animal which was able to feed like a plant; we end with an entirely dependent animal, like the liver-fluke that sucks the blood of the sheep's liver. This is thorough-going parasitism—a repulsive "life of ease," living upon the life of other living creatures, for the blood is the life.

"Behold the life of ease," George Meredith wrote; "*it drifts;* the sharpened life commands its course," which every reasonable being must desire to do.

The fuel of the body.—We see then that there

are many different ways of food-getting. If we leave the photosynthesis of green plants out of account as something by itself, on which everything else depends, and confine our attention to the needs of ordinary animals, we may make the obvious statement that food must be sufficient to replace all that is consumed. Without working at all, a man loses about eight pounds in a day, six of this being water. The body of an animal consists of organic compounds, inorganic salts, and water. The organic compounds include nitrogenous proteins, and non-nitrogenous carbohydrates and fats. Living means a using up of this material, and the food must replace what is lost. With a piece of cheese to represent proteins, a potato to represent the carbohydrate starch, a little butter to represent fat, and an apple to cover water and accessories, a man may make a perfect meal.

But food has not only to replace the material that is lost, as the water that comes into a whirlpool has to replace the water that goes out, it has to supply energy for the work the animal does; and one of the fundamental conditions of healthy living is that the food be sufficient to meet the expenditure. The energy-value of the food can be estimated in terms of heat, and the unit used is a Calorie, *i.e.*, the amount of heat required to raise 1000 grams of water 1° Centigrade. A gram of fat is worth 9·3 calories, a gram of carbohydrate 4·1 calories, and a gram of protein about the same. The protein food is really worth more (5·7), but it is a kind of fuel that is not fully burned up in the body, a consider-

able fraction being got rid of as waste (urea). This is one of the reasons why excess of protein food is to be avoided.

The coal that is put into a locomotive may be of special quality, but it is not specially prepared, and we see in the ashes that it is not altogether usable. If oil, which may be derived from coal, be used as the fuel, then the amount that is not burned up as the source of energy is very small. In the same way it is advantageous for an animal when there is not too much unusable material in its food, though a certain amount of bulk is often necessary. A theoretically perfect diet of fluid food would soon make a dog very ill.

But whereas the fuel in the furnace of the engine begins to be of use whenever it begins to burn, the food in an animal's food-canal requires to be prepared. It must be digested, that is to say dissolved and chemically altered in the food-canal, so that it may be absorbed by the blood and distributed through the body.

The evolution of menus.—In ancient days man ate what he could get, sometimes too little and sometimes too much. But we do not think enough of those early experimenters who gradually established a tradition of the edible—and sometimes paid for their lore in pains and death. What a day it was in the history of mankind when an observant and hungry wanderer caught sight of the big seeds of wild wheat, perhaps in Palestine, rubbed them clean in his hands, blew the chaff away, and had a mouthful which he was not hasty in chewing! It was so good that he made up his mind to sow and sow again. That was the

beginning of all the modern world's wealth of wheat!

The first period was one of rough and ready experimenting till a tradition of diet was established; and there can be no doubt that primitive man often had to eat far too much bulk in order to secure the requisite sustenance. We are paying for past history to-day, for our thirty feet of food-canal seems to be far too long for modern meals of highly nutritious food, served with approximate punctuality at regular intervals. Our civilisation as regards food has evolved more quickly than our body.

Criticism of meals.—But as man got a firmer foothold in the struggle for existence, when he learned to cultivate plants and to breed animals, to cook and to store, a second chapter began—preferential feeding. There was criticism and control of meals, especially amongst those who by luck or cunning got the upper hand. Empirically there was established a tradition not of what could be eaten with impunity, but of what was at once most enjoyable and most profitable. Gluttonous gorging became less and less common, except as a retrogression on feast days, when some rare savoury food was available in abundance. And of course gorging must always linger amongst those who live so near the margin of subsistence that they are rarely satisfied. The criticism of food has been an important factor in human history, and man's health would be better if there were more of it to-day.

Science of dieting.—The third chapter in the history is very modern—it is the growth of a

science of dieting. Without, let us hope, losing the traditional lore of the good cook—who is, in a way, as important as the good builder—there is arising a physiology of nutrition.

But the physiologists are telling us more than the gross energy-giving value of various foods; they are inquiring into the digestibility of different kinds, and their eyes are not shut to subtler qualities which are, as we say, "appetising." Both these factors vary notably with the individual, and are therefore somewhat elusive to scientific treatment. But the familiar saying "What is one man's food is another man's poison" is, *for normal persons*, true only within narrow limits. Some people can make much more of proteins than can others; but everyone must have his proteins.

Luxuries sometimes come to be more necessary than necessities, and it has been shown that many foods contain very small quantities of subtle extras which are almost more important than the aliment itself. These extras are the "accessory food-factors" or vitamins, which came into prominence during the Great War. Their discovery was made in connection with a mysterious Eastern disease called beriberi (common in Japan and the Philippines), which seems traceable to a too exclusive diet of polished rice. It was discovered that an extract of the rice polishings had a curative effect on the patients, and the inference became clear that the outer part and the germ of the rice-seed contain something whose presence means life (hence *vit*-amine or -amin), whose absence means disease or death. The something

has not been isolated in purity and the chemical composition remains obscure, but we know that it is an essential something—a vitamin.

It is now well known that beriberi is not confined to rice-eaters, but may occur in any persons who have to depend too exclusively on over-milled cereals, or on over-heated (*e.g.*, tinned) food-stuffs. The counteractive vitamin is present in "whole-meal" cereals (like Quaker Oats) and is especially localised in the "germ" or embryo-plant. It is abundant in peas and beans, in eggs and yeast; and it is present in milk and vegetables. It keeps well in a dried state.

Growth stimuli.—A working man requires food that will yield from 3000 to 4000 calories per day. Theoretically, he could get it all from a pound of pure fat; but practically he must have a mixed diet of proteins, fats, carbohydrates, and salts. But the work of recent years has shown that he must also have vitamins, which as a matter of fact a reasonable supply of fresh food always affords. Now, experiments on young rats and other convenient creatures revealed some ten years ago that even when the nutrition is theoretically perfect as regards the calories required and as regards its mixed nature, the animals fail to grow. And if the rats are already full grown they fail to keep up their normal weight. They are not making good their wear and tear. Yet it was shown that the addition of a small percentage of milk to the daily diet put everything right. Growth became normal and weight did not decline. The facts point to the existence of vitamins which are essential to normal growth. Subsequent

researches have led to the distinguishing of vitamins "A," soluble in fat, *e.g.*, in butter and yolk of egg, and vitamins "B," soluble in water, and present in such materials as rice-polishings, whey, and yeast. The latter are counteractive of beriberi, which is not the case with vitamins "A."

When an animal which is being fed with theoretically perfect food fails to thrive or grow, it must not be hastily concluded that what is lacking is a *vitamin*, unless vitamin simply means "x." Thus some recent experiments on pigs which did not get on well in spite of their excellent food go to show that the addition of plenty of earthy material put things all right.

Importance for man.—Man is always conquering some new corner of the kingdom which he has annexed in the name of science; and it looks as if he would be able to make an end of the old disease of scurvy. It was by no means confined to sailors and soldiers, explorers and gold-diggers; it was often rife in stay-at-home people before the days of potatoes. It is a terrible disease, due to a deficiency in the vitamins normally supplied in fresh food. The counteractives to the disease, known as water-soluble vitamins "C," are found in green vegetables and also in fruits such as oranges and lemons, and in many forms of fresh food, including potatoes not too well pared and not too well cooked. Of much importance is the discovery that if the Indian's *dhal* (peas, beans, and other forms of pulse) be soaked for a day and sprouted for a day, yet not allowed to ferment, it develops abundant anti-scurvy vitamins. But the

subsequent cooking if it is very thorough will do away with much of this value.

Attacking scurvy.—For anti-scurvy purposes pulse should be steamed, not boiled; or if boiled it should be in a small quantity of water which can be used as soup. There are infantile diseases approaching scurvy which are said to be due to a deficiency of fresh cow's milk; and we are simply selecting one out of many suggestions when we mention that two tablespoonfuls of the juice of a raw swede-turnip may suffice to turn the balance of an infant's life to the right side. Orange-juice is now generally recognised as a valuable adjunct to artificial foods or pasteurised milk because of the amount of vitamin "C" it contains. But what we are most interested in is the general proposition that man conquers by understanding. He finds out that certain diseases are due to deficiency in uncertain somethings or qualities which are present in minute amount in many foods. He has not isolated these in a pure state; he is only groping after their chemical composition; he has named them, though he does not know how they work; the most important fact is that he can use them, both in curing disease and in preserving health. But he must hasten slowly.

SINCE plants get on very well without a nervous system, we cannot regard nerves as essential to life. But when we look into the matter more closely, we find that even a tree is very sensitive, sometimes betraying its feeling of a passing cloud. The simplest organisms, which are single cells, without any "body" in the strict sense, have, of course, no nervous system, but they are very sensitive to stimuli. How much or how little their awareness amounts to, it is difficult to say, but they answer back to all sorts of provocations. Even a sponge, which may have a body as big as one's head, has no nervous system, indeed no nerve-cells at all. Yet it may shut one of its large exhalant apertures in the face of an intruding worm. In physiological language it is irritable, and although there are many living creatures without any nervous system or nerves, there is none without irritability or nervousness. For it is essential to a living creature to feel changes in the outer world, otherwise it could not answer back effectively. And living implies effective response.

Functions of the nervous system.—(I) It is essential, then, that the organism should be in

touch with its surroundings, and to bring this about is the first use of the nervous system. But it is possible without a nervous system at all, because of the general irritability of the living matter. (2) The second use of the nervous system is to spread the news through the body so that an effective answer may be given. There would not be much use in feeling a hot surface unless we could immediately draw our finger away. The earthworm feels the light tread of the thrush's foot. That is due to sensory nerve-cells. These carry the news to motor nerve-cells, which command the muscles to contract. It may be that the news comes to the motor nerve-cells not from the outer world, but from the inside of the body. Thus we cough, which means forcible muscular contraction, when a crumb threatens to go down the wrong way; and our brain, unknown to us, orders the production of more heat when the blood that passes through it is colder than it should be. (3) The third use of the nervous system is to bind the body into unity (integration) so that it works well as a whole. There is a combining of messages and a co-ordinating of commands; there is a storing of impressions and a registering of experience. This is the task of adjustor or connecting or internuncial nerve-cells. In some of these adjustor cells there is the local habitation of the inner life of memory, thought, and feeling. In other words their neurosis is correlated with psychosis.

The ground plan of the nervous system.—In the nervous system of a well-equipped animal like a bee or a dog there are three kinds of nerve-cells

or neurons. First, there are those that receive tidings from the outer world or from other parts of the body—the *sensory neurons* or *receptors*. The scout-cells, we may call them. Secondly, there are the nerve-cells that send out commands to the muscle-cells to contract or relax, to the glandular organs to secrete, to the blood-vessels to get larger or smaller. These are the *motor* or *efferent neurons*. According to their importance they might be fancifully called major-cells, captain-cells, and so on. We may gain in clearness by calling them executive officer cells Thirdly, as we have seen, there is another kind of cell, which is intermediate between the receptors and the motors, with one hand linked to the scout and the other linked to the executive officer. These are the G.H.Q. cells, the *adjustors*, or *internuncial nerve-cells*; and the higher the nervous system, the more adjustors there are. To pursue our analogy, the cells that do the actual work, the so-called "common soldiers" that fight the battles of life, are the muscle-cells, sometimes called effectors.

The Sundew on the moor answers back to the touch of the midge's feet by moving its tentacles, and the Venus Fly-Trap of Carolina swamps shuts its leaf-blade on its insect-booty. There is no nervous system in these or in any other plants, and yet there is effective movement. It follows therefore that we must not think of the nervous system as *essential* to vigorous action. All that we can say is that it helps greatly to that end, especially when locomotion is involved. Not even Neptune's Cup—a large sponge as big as a

bee-hive—has any nerve-cells; but it is sedentary, and there is no big animal that moves about that is without a nervous system. Long before there was any appreciable inner life of feeling and intelligence, the nervous system had its hands full in controlling locomotion. Movement was dominant before mentality, and it is safe to say that there could be very little psychical life until there was some centralisation of the nervous system into ganglia.

Professor G. H. Parker gives a simple example of the advantage of centralisation in connection with the sea-anemone. If a tentacle on one side of the sea-anemone's mouth be given a little piece of meat, it grasps it and transfers it to its gullet. If the tentacle be afterwards tempted with a little piece of filter-paper which has been dipped in beef-juice, it will do the same—which is very unprofitable. If the alternation is kept up for a short time, with the same set of tentacles, the sea-anemone takes the true food and the faked food equally well. Yet after eight to ten trials it learns, brainless creature though it is, to transfer only the true food to its mouth; it casts the paper-food into the sea. Now it is very interesting that if the same experiment be then made with the tentacles on the other side of the sea-anemone's mouth, they will take true food and faked food indiscriminately. They have not profited at all by the experience of the other tentacles. For the sea-anemone has no brain or ganglia; it has not more than a diffuse network of nerve-cells.

The nervous system of a higher animal.—The nervous system includes (*a*) the brain and its

cranial nerves, (*b*) the spinal cord and its spinal nerves, and (*c*) the sympathetic system. The larger part of the brain of a bird or a mammal consists of the cerebral hemispheres. In an intelligent mammal, like a dog or a monkey, and still more so in man, they cover over the other parts of the brain, and they have a much wrinkled or convoluted surface. If this superficial part or cortex, which is very shallow, were expanded so as to do away with its hills and valleys, it would cover a considerable surface, about a foot and a half square in man's case. It has grown out of proportion to the rest of the brain and out of proportion to the skull that contains it, and thus it has become convoluted. There are about 1,700,000,000 people living on the globe at present; but there are more than five times that number of nerve-cells in our cerebral cortex, though it only weighs about half an ounce. The number is estimated at 9,200,000,000; and their inter-connections are past telling.

What happens in the cerebral hemispheres? (1) It is a receiving station for news from the outside world, *e.g.* through the senses of sight, hearing, smell and taste, as well as messages from the body; (2) it is the headquarters from which come many commands to the muscles, *e.g.* to those of the leg, the trunk, the arm, and the face, including those involved in speech; but (3) it is especially the seat of association-processes, the effects of immediate stimuli being combined with those of past stimuli so that the character of the commands sent out is influenced by their combination. The cerebral hemispheres form the

seat of memory, inference, attention, control, and the other higher faculties.

The cerebral hemispheres are continued backwards in the "brain-stem," consisting of what are called the optic thalami, the optic lobes, the pons, and the medulla oblongata. Above the pons rises the cerebellum; and the medulla oblongata, which gives off the majority of the brain-nerves, is continued outside the skull, into the spinal cord. This runs down the canal of the backbone, giving off many double-rooted spinal nerves, which receive messages by their sensory fibres, and transmit orders by their motor fibres. In a lower Vertebrate, such as a skate, the brain shows all its parts lying in one plane, except that the cerebellum overlaps most of the medulla oblongata. One sees in order—from the front backwards—the cerebral hemispheres, the optic thalami, the optic lobes, the cerebellum, and the medulla oblongata. These are the five main parts of every Vertebrate brain.

What are the uses of the "brain-stem" and the cerebellum? The "brain-stem" might be compared to an immense number of telegraphic wires, such as we sometimes see by the side of a highway approaching a large town. Some of these nerve-fibres are conducting messages to the cerebral hemispheres, others are conducting orders to the body. But the brain-stem also contains many nerve-cells which are able to send an answer-back without, so to speak, troubling the cerebral hemispheres, and these in our body are concerned with regulating the breathing-movements, the pulse, the size of the fine branches of

the arteries, the activity of the food-canal, the movements of the head and eyes, and so on. In short, the "brain-stem" has a great deal to do with reflex actions and their co-ordination.

As to the cerebellum, it receives messages from the ear and from the muscles, and it sends out commands which maintain the muscular tone during rest and also co-ordinate muscular movements, so that they are harmonious and balanced. It is by the help of the cerebellum that we are able to keep our equilibrium. In our body the cerebellum is only about a ninth of the size of the cerebral hemispheres; but we can understand why in a trout, which has hardly begun to think, the cerebellum should be much the larger of the two.

The spinal cord is a highway for commands from the centres in the brain to active tissues in the body, and for incoming tidings from these tissues. The commands pass out from the spinal cord by the ventral, anterior, motor, or efferent roots of the spinal nerves (thirty-one pairs in man). The tidings pass in by the dorsal, posterior, sensory, or afferent roots of the spinal nerves. In each spinal nerve, within a common sheath, there are the two sets of fibres, but the direction of the nervous impulse is different in the two, and they separate as they enter the spinal cord. It was one of the great steps towards understanding the nervous system when the difference between sensory and motor nerves or nerve-fibres was first made clear by Sir Charles Bell.

But besides being a highway for centrifugal and centripetal nervous impulses, the spinal cord

includes many centres for reflex actions. To certain stimuli from the internal organs or from outside the spinal centres can give back an answer without requiring the help of the brain; but it is a very important fact that in man the spinal reflexes are much more subordinated to the brain than is the case in other creatures. Thus man can prohibit or inhibit his spinal cord from issuing the commands which are what might be called "natural"; and on this many of the "decencies" of human life depend.

When we sit with one knee over the other and receive a sharp tap just below the knee pan, we involuntarily give our lower leg a sudden jerk outwards. If we firmly clinch our fists during the experiment, the jerk will be more energetic. This is a familiar instance of a spinal reflex, though not perhaps the best that might be given. The knee-jerk takes place in a small fraction of a second, much quicker than blinking an eyelid, yet there has been time for a message to travel into the loin region of the spinal cord and for a command to issue forth to the muscle.

Finally, there is the sympathetic nervous system, a chain of ganglia or nerve-centres, lying outside the spinal cord but connected both with it and with the brain. It is beyond the control of our will, but is profoundly influenced by our emotions. The centres send branches to blood-vessels and viscera, and to a few muscles like that of the upper eyelid. When our face pales with fear or flushes with joy, the blood-vessels are reacting to messages from the sympathetic nervous system.

Reflex actions.—For most animals worthy of the name a condition of survival is a capacity for reflex actions. They must be able to give rapid and effective answers-back to frequently recurrent stimuli, whether from the outer world or from the parts of the complicated body. The capacity for reflex action implies that a message from sensory nerve-cells or receptors evokes a more or less immediate impulse from motor nerve-cells, commanding a muscle or a gland to be active or inactive. In most cases the links in the chain are: (1) sensitive cells, (2) sensory fibres and the sensory cells to which they belong, (3) adjustor or associative nerve-cells, (4) motor nerve-cells and their efferent fibres, and (5) the muscle-cells or gland-cells. Blinking an eyelid, coughing, sneezing, jerking our finger away from a hot or sharp surface, mouth-watering, are familiar examples of reflex actions. They occur independently of the will, though they may be often inhibited by control. They are established in the course of development. In other words, they are part of the inheritance. But many of the higher animals have the power of establishing *new* dexterities or habituations, which supplement the hereditary reflexes. It is plain that these secondary reflexes play a very important part in practical education.

Chapter VII How Many Senses are there?

It seems almost like sacrilege to attack the Five Senses, but we must harden our hearts, for there are certainly other senses besides those of smell, taste, touch, hearing, and sight. Our inquiry has been illumined by the recently published work on *Smell, Taste, and Allied Senses*, by Professor G. H. Parker of Harvard. He points out that we must widen the conventional idea of a sense-organ as a gateway of knowledge, or as a structure which initiates impulses to sensation. The need for widening the idea is plain when we turn from ourselves to simple creatures like sea-anemones. These animals have a network of nerve cells, but they cannot be credited with a central nervous system. Therefore we must not speak of the sea-anemone having knowledge or even sensation in the strict sense. Yet the sea-anemone has many sensory cells that respond to different kinds of outside stimuli. Their use is to excite action, to command muscles to contract. They are triggers by which the muscle is made to move, and this was the original use of sensory structures. In proportion as a central nervous system was evolved, the sensory structures began to be the gateways by which the raw

materials of knowledge enter in. Hence the convenience of the word "receptor" as a general term for a sensory cell or sense organ, whether its use be activating muscle or sending in information from outposts.

Our question then is: How many different kinds of receptors are there? And it is a very noteworthy fact that sensory nerve-cells tend to respond to one kind of stimulus and to that alone. By division of labour in the course of evolution there have come to be what might be called specialised scouts, each very alert to one particular kind of change in the environment, which may include the body as well as the outside world.

Sense of smell.—There is a tendency to underrate the importance of the sense of smell in man. This is due partly to the predominance of sight and hearing in human life, and partly to the fact that artificiality of habit and environment makes man careless in regard to the stimuli which come to him through the sense of smell. If he had to hunt for his food as a fox does, he would give higher rank to his olfactory organ. If he were a little less trustful in regard to the wholesomeness of what he eats, and a little more fastidious in regard to the air he breathes, he would think more of his nose. It often happens that modern man shows considerable deficiency as regards the sense of smell, and this is indeed the kindest way of accounting for his tolerance of stinks; but when there is deficiency it is more probably due to individual over-stimulation by odours like that of tobacco than to any racial degeneration.

There can be no doubt that continual nasal stimulation with strong odours such as snuff may induce a state of relative insensibility to other odours, such as the fragrance of flowers.

Triggers of reflex actions.—But there is another reason why man does not give the sense of smell its due, and that is to be found in the generally accepted idea that the senses are the gateways of knowledge. For if this be the view taken of the *rôle* of the sense-organs, it is impossible to put the olfactory sense of man on anything like the same level as the senses of sight and hearing. But the senses have another and more primary *rôle*—namely, to serve as the triggers of reflex actions. To an ordinary wild animal, like a wolf, the sense-organs are indispensable as the receptors of signals from the outside world; their ability to produce sensations and supply materials from which the mental life is built up is a secondary and subsequent use. But as man is mainly eye-minded and ear-minded, and hardly at all nose-minded, he tends to depreciate his nose. For it does not feed his mind as his eyes and ears do. Utilizing Professor G. H. Parker's clear and comprehensive memoir already referred to, we wish to say a little in regard to a sense which seldom gets its due.

Inside the nose.—Our two nasal cavities extend from the anterior nostrils, opening to the exterior, to the posterior nostrils, opening on the roof of the back of the mouth. Into these cavities there project three or four folds, and the whole internal surface is lined by a delicate membrane, partly glandular and partly bearing living lashes or cilia.

The folds are covered with a membrane very rich in blood vessels and capable of swelling up so as to close the respiratory passages. In traversing the folds the air is warmed and moistened and the secretion produced in the nasal chamber is believed to be hostile to injurious microbes carried in from outside.

On the uppermost fold and on the partition between the two nasal chambers there is a square patch, about one-tenth of an inch to a side, and this is the area sensitive to odours. It has a yellowish colour and consists in great part of slender elongated olfactory cells, each of which bears on its free extremity six or eight very delicate protoplasmic filaments or olfactory hairs. These cells are the exclusive receptors for odours, but there are also some free-nerve endings of minute branches of the fifth or trigeminal nerve. Some mammals have numerous smelling patches and others have few. Thus the South African aardvark, that hunts at night for white ants, has ten, whereas the number is small in seals and monkeys, which hunt by sight. In toothed cetaceans, like porpoises, the olfactory patch has practically vanished. It is interesting to notice that in true fishes—*e. g.* sharks—the nostrils are entirely smelling organs, whereas in toothed whales—*e. g.* dolphins and porpoises—they are entirely respiratory.

Effect of tobacco.—We have mentioned that on the smelling patches in our nasal chambers there are (1) olfactory endings connected with the olfactory or first nerve which carries the stimuli to the brain, and (2) free-nerve endings connected

with the trigeminal or fifth nerve. It appears that delicate odours, such as those of food, act only on the olfactory endings, whereas irritants, such as acetic ether, affect the trigeminal terminals. In the case of tobacco smoke it is probable that both sets of end organs are affected, the one kind by an aroma, the other kind by an irritant. Smokers do not say much about the latter.

What smelling implies.—It is almost unanimously admitted that the smelling surface is excited solely by material particles (vaporous or gaseous) which land there. We have seen a man find a Stink-horn fungus in a thick copse, tracking it down from a distance, just as a dog finds its master's glove in a meadow. But in reality there is no smell from a distance: particles borne through the air, usually in particular directions, reach the nostril, and if they settle on the olfactory patch they evoke olfactory excitement. The air that is breathed in quietly may pass through the nasal chamber to the back of the mouth without stimulating the olfactory cells; hence the biological meaning of "sniffing," which draws the odoriferous particles into contact with the olfactory patches.

There are ingenious ways of measuring the amount of a substance that is required to produce a distinct sensation of smell, and the most interesting general result is that in many cases very small, often infinitesimally small, amounts of the substance are sufficient. Everyone knows how long a minute quantity of natural musk will continue to give a distinct odour to a room, and artificial musk, probably the most potent

of all odoriferous substances, is about a thousand times stronger than natural musk. The general view is that vaporous and gaseous particles are caught in the watery mucus covering the free surface of the olfactory cells and their "hairs," and that stimulation requires some form of solution of the particles. In those fishes that have a sense of smell, as has been proved for sharks and dogfish, American catfish and killifish, the stimulating material is carried in the water that passes freely in and out of the nostril.

Professor Parker points out that olfactory exhaustion is readily induced by strong odours. If we sniff oil of lemon or oil of orange for a few minutes we soon cease to smell it at all. But we are never exhausted by the delicate fragrance of wild thyme or sweet vernal grass. And just as there are people born colour-blind, so there are people who are totally or partially "anosmic." The deadening of the sense of smell during "a cold in the head" is mainly due to the smothering of the olfactory cells by the profuse secretion.

The "olfactory prism."—Many attempts have been made to classify odours, one of the best being Henning's "olfactory prism." The three upper corners are occupied by three fundamental odours—flowery (*e. g.* heliotrope), fruity (*e. g.* orange), and foul (*e. g.* sulphuretted hydrogen); the three lower corners are occupied by other three fundamental odours—spicy (*e. g.* cloves), resinous (*e. g.* eucalyptus), and burnt (*e. g.* tar). On the intermediate lines and surfaces are marked the numerous intermediate odours, while in the interior of the prism there are indicated those that must be

called "mixed." Behind this ingenious arrangement there lies an incipient attempt to link the fundamental odours with various lines of chemical constitution.

In many of the backboneless animals, such as ants and bees, the sense of smell is important in connection with way-finding or "homing," with the recognition of kin and sex, and with the detection of enemies. These uses persist in some measure among higher animals, but from first to last the sense of smell has its greatest importance in connection with food. By smell the animal tracks the hidden or distant booty; by smell the animal avoids what is unpalatable or unwholesome. Subtler than these functions, however, is that by which the pleasant odour of the meal pulls the trigger of digestive processes and prepares for the utilisation of the food even before it is eaten. Subtler still is the association of pleasant odours with pleasant pictures and memories, and, in man's case at least, with pleasant feelings and ideas. It would do man no harm if he paid more heed to the old advice: Follow your nose!

The Sense of taste.—As with smell, so as regards taste, there is a tendency to underrate the importance of the sense. Man is so predominantly eye-minded and ear-minded that he naturally ranks the other senses on a lower level, especially when he thinks of the senses as doors of knowledge through which his mind is furnished. But the sense-organs have the further function of being outposts for receiving useful signals and for evoking almost automatically those useful answers-back which we call reflex actions. The sense

of taste may save a man's life by prompting him to turn away from or reject unwholesome food. Moreover, the sense of taste, like that of smell, is important in setting agoing the secretion of the digestive juices and other important operations by which the food is utilized in the food-canal.

It is not for nothing that "our mouth waters" at the sight of palatable food, and the gustatory preparation for the meal may be of value even if it does not go the length of evoking profuse salivary secretion.

The seat of taste.—There are some fishes that have "taste-buds" on the sides of their body, and there are many instances of taste organs in situations quite apart from the mouth. But everyone knows that in man the seat of taste is in the mouth. The taste-buds are situated not only on the tip and lateral dorsal surface of the tongue, but on other places such as the soft palate, the epiglottis, and the wall of the pharynx. In early childhood they are more widely distributed than in the adult. Thus, the inner surfaces of the cheeks are gustatory in young children. It may be noted that there is much individual variation as well as age-variation in the number of taste-buds, and that an average number for a single papilla on the tongue of an adult is about two hundred and fifty. There is gustatory individuality justifying the phrase—"a question of taste."

Taste-buds.—A taste-bud is a spindle-shaped or flask-shaped group of cells embedded in the mucous membrane, and usually opening by a

small pore. The group consists of a few elongated taste-cells, each with a delicate process or hair projecting out of the pore or into its canal when that is present. As the older taste-cells become exhausted and disintegrate, new ones are formed to take their place. The buds are richly innervated by fibres which issue in mammals from at least three of the brain-nerves. It seems probable that when a gustatory twig, growing out from a nerve, reaches a spot in the epithelium, or covering membrane, it gives out some stimulating substance like a hormone, which provokes the adjacent cells to form a taste-bud.

What happens when we taste.—If a substance is to be tasted it must be brought into contact with the taste-buds in the form of a watery solution. Particles from a distant object may be detected by smell, but taste implies actual contact. In other words, taste-cells are contact chemical receptors. It follows that a solid substance cannot be fully tasted unless part of it is chewed, dissolved in the saliva, and moved about so as to come into intimate contact with the taste-cells.

The stimulation of these cells is followed by a message to the brain and the production of a pleasant or unpleasant sensation. In the last case there may be a reflex rejection of the unpalatable substance, and this has doubtless sometimes been of life-saving importance—especially long ago, when man was still very ignorant in regard to the wholesome and the unwholesome. When a person dies through having swallowed the wrong medicine it means that he did not give the draught

time to be tasted. The average time between a taste-stimulus and the answer-back is estimated at 0·167 of a second, but this varies considerably according to the nature of the substance tasted.

A familiar experience is that certain solutions so affect the tongue that they change the taste of some substances. A mouth-wash of potassium chlorate so changes the taste-buds on the tongue that even distilled water seems sweet. Connoisseurs are agreed that certain fruits, enjoyable enough in themselves, spoil the flavour of wine, and there is probably a gustatory as well as a digestive justification for many familiar mixtures, such as strawberries and cream, or liver and bacon.

Varieties of taste.—The classification of tastes is on a firmer basis than the classification of odours. For it seems quite plain that there are three or four quite distinct tastes, which may have separate receptors. These fundamental tastes are sour, saline, sweet, and bitter. The sour taste is excited by acids or similar substances which give rise to hydrogen ions on passing into aqueous solution. The salt taste, like that produced by common salt, is due to ions of chlorine or the like. The bitter taste is well represented by quinine and strychnine. The sweet taste, like the bitter one, is primarily associated with organic substances, such as sugar and other carbohydrates. But the most interesting point is the most general one, that the four fundamental tastes are so distinctive that some authorities speak of four senses of taste.

Chemical senses.—Recent investigations have led physiologists to lay emphasis on the common

features exhibited by a number of sense-organs of which the olfactory patches in the nose and the taste-buds in the mouth are the most familiar examples. There is a general but acute chemical sense in the skin of many animals, such as dogfish and fishing-frog. It is more restricted in terrestrial vertebrates, but even in man it is well known. Thus the vapour of ammonia not only irritates the nose but causes the eyes to water.

If a piece of meat is held close to the flank of an American catfish, the animal may turn suddenly round and snap it up. This is probably due to the presence of taste-buds on the sides of the body; and another set of receptors is to be found in the lateral line. If these two sets of sensory structures are put out of action, the fish no longer responds to the piece of bait held near its flanks, yet it answers back to the administration of acids and salts. The fish has a chemical sense. And, as Professor Parker says, man also has a common chemical sense, as contrasted with his sensations of smell, taste, touch, or pain :—"The curious feeling that comes from vapours that irritate the eyes, nose, or even the mouth has not the remotest relation to touch, smell, or taste, and is only distantly suggestive of pain. Pain, however, is easily separated from the common chemical sense by the use of cocaine, and we are, therefore, entirely justified in concluding that the common chemical sense is a true sense with an independent set of receptors and a sensation quality entirely its own."

A puzzling sense-organ.—In many mammals

and in some reptiles there is a peculiar paired sense-organ (the organ of Jacobson) lying in the nasal chamber and communicating with the cavity of the mouth. It has sense-cells like those of the olfactory patches, and is very probably an accessory smelling organ. It is present in man in a degenerate state, and it may entirely disappear in the adult. The organ is an item in the museum of relics which we carry about with us.

The sense-organs we have spoken of—the olfactory patches, the taste-buds, the organ of Jacobson (or vomero-nasal organ), and the nerve-endings that respond to chemicals—form a series and have a number of features in common.

As Professor Parker points out, they are *chemo-receptors* responding to chemical substances in solution. Even in the case of odoriferous particles it seems that they must reach the susceptible cells through a watery medium. The dissolved material must be chemically active if it is to be sensed, and it must come into actual contact with the terminals. In this respect the stimulus is very different from that involved in touch or hearing. It follows that the chemo-receptors must be readily accessible, either lying on the surface or communicating with it by pores.

Effect of a heavy cold.—The distinction between taste and smell is not very deep, but smell deals with very minute particles which can be carried from a distance in air or in water, whereas taste usually deals with concentrated solutions, especially those that proceed from food. It is a familiar fact that if we pinch our nostrils we eliminate

smell, but leave taste; and the simple experiment is very instructive, because it shows that a large proportion of our food-sensations are due not to taste but to smell. This is corroborated by the common experience that food appears relatively "tasteless" when we have a heavy cold. It is, in reality, the smell rather than the flavour of the food that is most seriously interfered with. If we try to put the chemical senses in historical series, the sense of smell must be ranked first, the general chemical sense second, and the sense of taste third.

The sense of taste is of biological significance mainly in relation to the discrimination of wholesome from unwholesome food and as a preparatory stimulus which makes meals more profitable. But part of the preparatory value of taste depends on the prior condition of being *hungry*!

The senses we have mentioned—perhaps over half a dozen already—have this in common, that their triggers are pulled by chemical substances in solution directly applied to the sensitive surface. They are therefore called chemoreceptors, and are in marked contrast to the mechanico-receptors of touch, pressure, and hearing. "In these organs," Professor Parker writes, "the appropriate stimulus is a deforming pressure which may be exerted by an impinging or vibrating material that does not necessarily touch the terminal organ itself, but may act through a considerable amount of intervening tissue." A mechanico-receptor like a touch organ or a hearing organ may be deeply lodged and well protected, but a chemo-receptor, like a smell organ or a

taste organ, must lie on an exposed surface, or be provided with pores leading to that surface.

The insight of Aristotle is illustrated by his recognition of the fact that the sense of touch, which he regarded as fundamental, included several sub-senses; and modern physiology has elaborated the fact. The skin-receptors, which are excited by deforming pressure—the clasp of our friend's hand—are quite different from those by which we become aware that his hand is hot or cold, or from those which make us wince at the strength of his grip. In other words, the tactile sense is quite different from that of the heat-receptors and the cold-receptors; and the sense of pain is distinct from them all. In mentioning the heat organs and the cold organs of the skin we have obviously passed beyond chemo-receptors and mechanico-receptors to a third series, that of the radio-receptors, which respond to changes in radiant energy; and the climax of these is the eye. Lest we lose the wood in the trees, let us emphasise the threefold classification: receptors respond to chemical, mechanical, and radiant stimuli. The skin contains receptors which respond to all three kinds of stimulus, but no single receptor is susceptible to more than one kind. On the other hand, one complex stimulus, such as the explosion of a bomb, may affect many different kinds of receptors.

We have not, of course, exhausted the list of sensory receptors. Thus the ear of most of the invertebrates that have such an organ is for balancing, not for hearing, and this primary equilibrating function persists in our semi-circular

canals. In the course of evolution there has been extraordinary division of labour and specialisation. It would take us too far to speak of the sense of pain, the sense of hunger, the sense of thirst, and more besides. Instead of our having five senses we have nearer a score! We forestall the wit who is sure to ask—"And what about common sense?"

Chapter VIII *Animal Behaviour*

In studying animal behaviour the difficulty is to steer a middle course between generosity and stinginess. To credit animals with reason, which means experimenting with general ideas, is, in all probability, too generous. To try to reduce them to the level of automatic machines is certainly too stingy. The fact is that the behaviour of animals is often intelligent, often instinctive, and often a subtle mingling of the two. But it is necessary to attach precise meanings to these terms.

Big brains and little brains.—In a famous paper, many years ago, Sir Ray Lankester drew a firm distinction between the "little-brain" type of animal, seen at its best in ants, bees, and wasps, rich in inborn instinctive capacities for doing dexterous things, but very slow to learn; and the "big-brain" type, seen at its best in horse, dog, and man, relatively poor in ready-made capacities for precise pieces of behaviour, but more than making up for this by great educability. Each of these lines of evolution has its merits; the instinctive capacity does not require learning or apprenticeship, the intelligent behaviour is ready for emergencies and departures from routine. In many cases, as in birds, a large section of

behaviour (*e.g.* nest-building) may be instinctive; and yet it is open to the creature to "call up" intelligence when a novel situation arises.

Intelligent and instinctive behaviour.—The other day we saw a lady give her cat its milk in a vessel which had an opening too narrow to allow Puss to get her mouth in. With great deliberation the cat put its paw into the milk, withdrew it, and licked it; and repeated the performance, not without reproachful looks at its mistress, until the meal was over. We were told that the cat had discovered the method, and the performance had certainly the smack of intelligence. There is always in intelligent behaviour some spice of judgment, some putting two and two together, some "perceptual inference."

On the other hand, a young spider, which never made a web before, may make its masterpiece true to the specific pattern the very first time. It does it without any model to copy, and with no trace of the prentice hand. Sometimes it can make the web in the dark, or in the course of a forenoon. This is instinctive behaviour, depending on hereditary prearrangements of nerve-cells and muscle-cells, though probably never without its psychical aspect—a suffused awareness and a background of endeavour. But, apart from theory, the fact of observation is certain, that inexperienced animals suddenly blossom out into extraordinary intricacies and niceties of behaviour, perfect the very first time, not requiring to be learned. *This is instinct.*

A reflective Polar bear.—We were watching a Polar bear in the beautiful Zoological Gardens at Edinburgh, and we had the good fortune to witness a clear instance of intelligent behaviour. The benevolent visitors had thrown buns towards the peninsula of rock on which the Polar bear sat—a peninsula projecting into the water of the quarry forming the bear's artistic home. Many of the buns had fallen short, and were floating on the surface. With a plunge the Polar bear could have retrieved them all, but it was averse to the bath. So, what did it do but come to the edge of its peninsula, and scoop the water with its great paw. It scooped and scooped till the buns came drifting past, and the Polar bear got them all. Now this was experimental or reflective behaviour. The bear adapted old means to a new end.

Sensory alertness.—There are many pitfalls for the unwary student of animal intelligence, and we do not delude ourselves by supposing that we always escape them. One of these pitfalls is ascribing to intelligence what is readily explicable by sensory alertness. Thus the ants' world is very largely a "smell-world." The ant finds a honey treasure by smell; it acquaints its neighbours of the fact by smell and by touch; it acts as guide to the treasure-trove by smell; it gets home again by smell. But there is not necessarily much intelligence about this.

Two American investigators, Professor J. B. Watson and Dr. K. S. Lashley, took marked sooty terns and noddy terns from their nests on the Tortugas Islands, and, putting them in well-

provisioned closed baskets, conveyed them on board steamer to Havana, 108 miles to the north. Some of them were back on their nests next day, though normally these particular terns do not go north of the Tortugas on their migratory movements. Even when they were taken north to near Cape Hatteras, 850 miles north of the Tortugas, there was a percentage of safe returns. Now we are quite in the dark as to the physiological basis of this "homing" capacity; but there is no reason to believe that pondering over the points of the compass enters into the business at all. It is a question of sensory endowment.

Forming associations.—Another pitfall in judging of the intellectual value of particular instances of behaviour has to do with the formation of associations. Nothing is commoner than an exclamation at the supposed "cleverness" of a dog which acts in a precise way when it hears certain words uttered or when it sees its master take a particular key off the peg. But there is little real cleverness here beyond the precision of the hearing or the seeing and the retentive registering of the association between the word or sight, on the one hand, and a particular action on the other. There is no doubt that certain dogs, asked in a quiet, unemphatic way to go to the next room and fetch the newspaper from the floor, will do so without fail, and scores of things much more wonderful. But this establishment of associations is seen in fishes, which are very dull-witted, and even as low down in the scale as water-snails. On the other hand,

when a dog, carrying a basket of eggs in its mouth, comes to a stile, and pushes its precious burden through underneath before itself taking a flying leap over, the atmosphere has changed to intelligence. The carefully adjusted behaviour of a collie dog in collecting the sheep or separating out two mixed flocks is at a high level of intelligence, helped by long experience, no doubt, and by co-operation with man. The behaviour of a shunting horse at a small railway siding is also intelligently plastic.

Profiting by experience.—We have to do with some grade of intelligence whenever it seems legitimate to say that the animal shows an appreciative awareness of the situation and is not non-plussed by slight changes, as predominantly instinctive creatures tend to be. The young thrush *learns* to break the shells of snails on its anvil in the wood. The rooks *learn* to take the freshwater mussels up to a height and let them fall on the gravel, so that the shells are broken. It was attentive of the chimpanzee to learn to hand over four straws when asked for four, but it was intelligent to save time by folding one of three straws double so that two ends showed between its finger and thumb. Still more intelligent was it to straighten out the bent straw and pick up another one, when the reward was withheld because of its trickery. The chimpanzee showed appreciative awareness of the situation.

It is probable that the educability of big-brained animals like horses and dogs is much greater than is usually imagined, for we get

glimpses of remarkable possibilities in those which have entered into intimate partnership with man. It must be remembered that it is not profitable for a wild animal to be more intellectual than the conditions of its life require, and it may be that working in partnership with man serves as a liberating stimulus to the dog's intelligence, taking the place of something that has been absent since man succeeded in domesticating a young member of a pack.

Which are the most intelligent animals?—Birds and mammals are, of course, cleverest. Among birds, we should place highest the rooks, the cranes, and the parrots—all social. Among the mammals the palm must be given to gregarious carnivores, gregarious elephants, gregarious horses, and so on. There is no doubt that social organisation favours the development of wits, and there is no argument in a circle in saying that the growth of wits often favours sociality. Another important factor is a vocabulary, such as we find in rook and dog. A great advance was made by monkeys and apes, which are endowed with a restless experimental brain at a higher level than in other mammals. "Until at last arose the man."

Chapter IX The Blood

MORE than two thousand years ago Aristotle divided animals into the sanguineous and the non-sanguineous, the line of separation corresponding to that which we now draw between the backboned and the backboneless. In this classification he was technically wrong, since there are many backboneless animals with blood. But it is probable that he was far less wrong than appears at first sight, for he was doubtless thinking of red blood, and in the majority of backboneless animals with blood there is no red pigment. In most molluscs, insects, crustaceans, and so on, the faintly bluish pigment of the blood (hæmocyanin) is scarcely discernible on ordinary inspection, and it is less effective in oxygen-capturing than the red blood-pigment (hæmoglobin) of vertebrates. Both are proteins in combination with a metal-containing substance, but the metal in the case of hæmoglobin is iron, whereas in the case of hæmocyanin it is copper. It may be of interest to give the formula of a molecule of hæmoglobin according to a good authority. It is Carbon 758, Hydrogen 1203, Nitrogen 195, Sulphur 3, Iron 1, and Oxygen 218; or, more briefly, C 758, H 1203, N 195, S 3, Fe, O 218.

When we look into an open rain-water barrel we sometimes see " blood-worms " jerking themselves up and down, and shining out very conspicuously in their vivid red colouring. They are the young of a kind of midge, the harlequin fly or Chironomus, and they have got possession of hæmoglobin. This is very interesting because, as we have mentioned, hæmoglobin has a greater oxygen-capturing efficiency than hæmocyanin, which most insects have as their blood-pigment. It follows that the aquatic larvæ of this kind of harlequin fly can thrive in water where the oxygen is abnormally scarce, where for many aquatic insects life would be very difficult or impossible. This illustrates one of " Nature's ways " : the possession of hæmoglobin gives the blood-worm a key which opens a particular door of opportunity, closed to most of its relatives. We are not wandering from the point, for we have given a vivid instance of one of the normal functions of the blood—namely, oxygen-capturing.

A body is a city of cells, and the comparison is of itself enough to suggest the necessity for blood or some other internal medium. There must be in the city some means of distributing food and water and removing waste; and so it is with the body. But the need in the body is often much more urgent. Thus even into the most congested parts of the worst of cities the air penetrates to a degree which would not be possible in the recesses of a complex body, were it not for the blood. This raises the question: How did animals get on before there was any

blood? For many backboneless animals are indeed bloodless, as Aristotle said. As long as an animal is small, there is no difficulty in understanding how all the parts of its body may be supplied with water, oxygen, and digested food, or cleansed from waste. The answer is in the word diffusion; and the same "seeping through" method holds in the main in the plant world.

In a sponge as big as one's head, in a jelly-fish large enough for a mermaid to sit on, in a huge colony of coral the size of a cart-wheel, in a sea-pen four feet high, and so on, we have to do with bodies of considerable size, and yet without blood. But in these cases there are canals penetrating the whole, and there is no need for any special distributing medium. At a higher level, as in threadworms, there is a fluid filling the cavity of the body, but there is not as yet any blood. Perhaps we may say that ribbon-worms or nemertines were the first animals to have a closed-off blood system, and they are the lowest animals in which hæmoglobin occurs. In many animals, such as sea-urchins, the body-cavity fluid seems more important than the blood; in earthworms the body-cavity fluid is the main food distributor while the blood carries gases and nitrogenous waste products; in insects the blood flows for most part in ill-defined spaces throughout the body and there is no separate body-cavity fluid. To cut a long story short, many gradations lead on to what we have in ourselves—(1) a closed and continuous system of arteries, capillaries, and veins containing blood; and (2) another

system of lymph-vessels whose fine thin-walled capillaries intervene, like "middle-men," between the blood-capillaries and the tissues. There is diffusion of nourishment and oxygen from blood to lymph and thence to the tissues; there is diffusion of waste-products and carbonic acid gas from the tissues to the lymph, and thence to the blood.

In a normal man the blood weighs about a twentieth of the whole body, but if he goes to live in Johannesburg, which is 6000 feet above sea-level, his red blood corpuscles will greatly increase in number, and the proportion of blood-weight to body-weight will increase. The increase in the number of red blood corpuscles at great altitudes is a good example of individual plasticity; it means an increased capacity for capturing oxygen, which is scarcer in the rare atmosphere of the heights.

The fluid of the blood is a very complex mixture. It contains, on the plus side, dissolved proteins, a little sugar, a little fat, much oxygen, and some salts, which in their nature and proportions suggest in a very striking way the composition of sea water, especially that of the ancient sea inhabited by the animals that first had blood! We cannot shake off the lien the past has upon us; when our head throbs we may hear the primeval ocean breaking on the shore. But, as we were saying, the fluid of the blood is a very complex mixture, and it contains, on the minus side, some nitrogenous waste (especially urea) and carbon-dioxide (chiefly united with carbonate of sodium). It

is hardly necessary to say that the bulk of the blood (a little over 90 per cent.) is water. Make of it what you like, life is a very watery business.

But the blood fluid is a mixture much more intricate than we have yet indicated. It carries from the ductless or endocrine glands the subtle hormones and chalones, invisible chemical keys searching for tissue-locks, which they open or close as the case may be. Then there are the counteractives or anti-bodies which parry the thrusts of poisons, especially those that microbes make. Another of these subtleties is anti-thrombin, which prevents the blood from clotting in normal blood-vessels. In some old or diseased persons a clot may form in certain blood-vessels of the brain, and this often spells paralysis and death.

A tissue, such as a piece of flesh, or brain, or fat, or gristle, is a collection of similar cells performing similar functions; and blood is a tissue —a fluid tissue. The complex medium we have spoken of is, as it were, peopled by millions of living units or cells—the red blood-corpuscles and the white blood-corpuscles. Of the latter in higher animals there are several different kinds, including the active phagocytes, which sometimes migrate out of the blood-vessels altogether in their urge to deal with intruding microbes. It is not possible to form any conception of the number of red blood-corpuscles we have in our body, though they can, of course, be counted. We may say, however, that as there are five million red blood-corpuscles and about twenty thousand white blood-corpuscles

in a drop smaller than the head of a pin, say, a cubic millimetre, and as we have in our body about ten pints of blood, which the heart drives about a mile every day, it follows that if the blood-cells were arranged shoulder to shoulder in single file they would stretch two-thirds of the way to the moon! If anyone fails to follow this argument he should read Dr. Ronald Campbell Macfie's *Romance of the Human Body*.

What we wish to make clear is simply the general idea that the blood is a common medium from which all the tissues of the body take and to which they all give. It distributes digested food; it carries oxygen from the place of capture (the lungs) to the place of combustion (muscles, etc.); it carries carbon-dioxide from the place of combustion to the place of liberation (the lungs); it collects the subtle nitrogenous waste-products of the body and gets rid of them in liver and kidneys; it distributes hormones and animal heat; it contains subtle anti-bodies which counteract poisons. The cells of the blood have much to do, and they are continually being worn out. But their numbers are continually recruited from the red marrow of the bones and from the spleen. "The blood is the life."

Chapter X — Hot and Cold

EVERYONE is familiar with the warmth of the body. We all dislike a cold hand, and hasten to say, "A cold hand means a warm heart." If we put our hand on a cow's neck we feel how comfortably warm she is; if we manage to hold a finch in our hand we find that its body-temperature is considerably higher than ours, which is normally about 37° C.; if we could test the egg-laying, spiny ant-eater, we should find that the creature was about 7° C. cooler than we are, but that we could raise its temperature greatly by taking it into a warm room or even by teasing it.

Animal heat.—What is this animal heat and what is its significance? In higher animals the animal heat is mainly due to the combustions or oxidations that go on in the body, especially in connection with the muscles, which are heat-producing even when at rest. The source of the heat is to be found in the chemical reactions that take place, and these depend on the food, and the food in the long run is derived from plants, and the plants get all their energy from the rays of the sun. So the warmth of the animal body is due to the transformation of

the energy of the sun. For no living creature ever produces new energy; it never does more than transform and store.

The great value of the animal heat is to make the chemical reactions of the body go on more rapidly and uniformly; and thus we can understand why the so-called warm-blooded animals, namely the birds and mammals, which keep up a constant temperature, year in year out, day and night, are in a stronger position than the so-called cold-blooded animals, like reptiles, amphibians, and fishes which tend to approximate in their body-temperature to that of the surroundings. We may say that we are "cold" or "hot," but our body-temperature does not appreciably rise or fall as long as we are not ill.

Warm-blooded and cold-blooded. — Warm-bloodedness is the power of sustaining a constant body temperature. If the bird or mammal is becoming too cold, the lowered temperature of the blood pulls the trigger of a heat-regulating centre in the brain, and orders are sent out to the muscles to produce more heat, and to the blood-vessels in the skin to contract. To counteract too high a temperature, the animal may remain quiet, or it may increase its breathing movements like the panting dog, or it may sweat profusely, which also brings down the temperature.

If a young nestling is exposed for a short time on a cool evening, its temperature becomes lower and lower, and it dies. For in the young bird, the heat-regulating arrangements have not yet been perfected. In the same way, there are

some mammals which show the grip of the past upon them, for they are imperfectly warm-blooded; they have not quite got free from the cold-bloodedness of their reptilian ancestors. Some of these imperfectly warm-blooded mammals make a strength of their weakness, as we shall sec, by hibernating. We wish to illustrate the biology of animal heat by inquiring into two very different phenomena—winter sleep and sweating.

Winter sleep.—There are many different ways of circumventing the severity of winter, which means short commons as well as cold. Thus some cold-blooded animals, like the tortoise and the frog, sink into a state of lethargy and discontinue the ordinary routine of vital processes. They can endure a very low body-temperature without fatal results, but if the cold be so great that the water in the body begins to freeze then they die. But the winter lethargy of some cold-blooded animals is rather different from true hibernation, which is restricted to certain mammals, such as the spiny ant-eater, the hedgehog, the bat, the marmot, and the dormouse. They are imperfectly warm-blooded, and when winter comes they are unable to produce enough of heat to compensate for their normal loss. What happens is that they give up attempting the impossible and sink into a state of inactivity within a confined space, to the temperature of which their body-temperature tends to approximate. If they fell asleep in an exposed situation they would be frozen to death; but in a snug hole or sheltered nook the coma is more or less

safe. If the sleeping room becomes very cold the inmates pass from sleep to death.

During the ordinarily successful winter sleep there is no income of food, and there is no getting rid of waste; the heart beats very slowly and feebly; respiration has practically stopped; some stored fat is usually burned away to keep up a modicum of animal heat, compensating for the inevitable loss.

Not always a winter sleep.—It may be that the relative warmth of the sleeping room and its close air help to keep the sleeper sleepy, and that an accumulation of waste-products in the body brings about "auto-intoxication," but we have to remember that the winter sleeping is a racial, not an individual, characteristic. In the course of ages it has been engrained in the constitution as an internal rhythm, normally but not necessarily corresponding to the external seasonal periodicity. Woodchucks may go to bed while the weather on the Adirondacks is still warm and pleasant, and unusually severe cold may waken a hibernator.

There is a good deal of truth in one of the hard sayings of an old investigator, that winter sleep is not sleep, and that it has nothing to do with winter. There is no distinction between the summer sleep of the tenrec of Madagascar and the winter sleep of the European hedgehog.

Light and heavy sleep.—The winter sleepers differ considerably in the soundness of their slumbers.

The sleeping hedgehog may be immersed in

water for twenty minutes or subjected to noxious gases without awakening; and the marmot is another heavy sleeper. The dormouse, on the other hand, is a rather light sleeper; and many bats awaken when there is a spell of fine weather in mid-winter. Artificial disturbance of deep hibernation is said to have an injurious effect on the constitution; it disturbs the rhythm of life, and may be fatal.

When the reawakening comes and the animal becomes active again, the body temperature is rapidly restored to the normal. Thus Dr. Pembrey found that an awakened dormouse raised its temperature by 19 degrees in 42 minutes.

Hibernators and non-hibernators.—If it be asked why a hedgehog hibernates, while a mole does not, part of the answer is that the mole is a burrower who finds earth-worms and grubs beneath the reach of the frost's fingers even in midwinter. If it be asked why bats hibernate, while birds do not, part of the answer is that the great majority of North Temperate birds evade the winter by migrating. If it be asked why marmots hibernate, when stoats do not, part of the answer is that the stoat turns in winter into the white ermine, and that the white robe makes the problem of facing the cold much easier. If it be asked why the jerboa of the Kirghiz steppes hibernates, while the squirrels in the forest further north do not, the answer is in part that the squirrels accumulate stores of food.

Generalising this, we may say that the non-

hibernating mammals have very often some special adaptation or fitness that enables them to cope with the winter, or, if they have none, they have hardy resistent constitutions, as in wolves and foxes.

But we have already hinted at the other half of the answer. Mammals are descended from cold-blooded animals; some are less perfectly warm-blooded than others, having some imperfection in their heat-regulating arrangements. These have made a virtue of necessity by becoming hibernators. They cannot sustain the temperature at the level required for a continuance of everyday life, so they relapse into a life-saving cold-bloodedness and inactivity. They pass into a state in which they can fast without feeling the worse for it; they lie low with dulled sensitiveness instead of fretting themselves to death in a hopeless struggle with the cold and scarcity.

In other words, the winter sleep is a slowly wrought-out adaptive reaction of survival value. To all this, however, must be added the idea that the long rest of the winter sleep—a rest even from eating—gives an opportunity to processes of rejuvenescence to stave off that senescence which is the universal tax on structural complexity.

"*In the sweat of thy face.*"—On warm days many people verify the judgment pronounced on Man after his first disobedience: "In the sweat of thy face shalt thou eat bread." What is this sweat? Why do we perspire?

Sweating is peculiar to mammals, and there are some that dispense with it. What actually occurs is that corkscrew-like sweat-glands are filtering out water (with traces of salts and volatile products) from the surrounding blood, and getting rid of it on the surface through minute apertures. What are called the pores of the skin are the minute openings of the sweat-glands, and there may be two or three thousand on a square inch. There are other glands in the skin, called sebaceous, which manufacture a fatty substance, keeping the skin and the hair in good order, but they usually open into the little moats from which the hairs grow out.

Keeping up a water-circulation.—When perspiration is moderate and the air dry the sweat evaporates instantaneously, but in conditions of great heat and moist air large drops are formed and we see or feel them trickling down the face like tears. The skin may be seen glistening with drops of sweat, and places like the palm of the hand become very moist. The greater part of sweat consists of water, and it should be remembered that living matter itself contains a large amount of water, sometimes over ninety per cent. The water that is got rid of in sweating came from the blood, and the blood absorbed it from the food-canal and from the tissues of the body. Two or three pints of water are on an average got rid of by the sweat-glands in the course of twenty-four hours, and it may be said that the sweating helps in keeping up a useful internal water-circulation. But this cannot be

its chief meaning, for some animals, birds for instance, do not sweat at all.

A sign of hard work.—Along with the water of the sweat there are small quantities of fats and volatile fatty acids, traces of albumin and the waste product urea, and also minute quantities of inorganic salts. It is also well known that certain substances taken in as part of food and drink may reappear in the sweat. Thus the second suggestion is that sweating may be a means of filtering out certain waste-products or by-products that the blood collects. But while there is some truth in this, it cannot be the main answer to the question, *Why do we sweat?* for the quantities filtered out are very small.

The most important part of the answer becomes evident when we notice the great increase of sweating when there is very warm weather or when very hard work is being done. Workmen engaged in stoking fires have been known to get rid of three and a half pints of sweat in forty-five minutes, and as much as five pints in seventy minutes. This seems almost incredible, but we must remember the prodigious number of sweat-glands. In his vivid *Romance of the Human Body*, Dr. Ronald Campbell Macfie tells us that "the total number of sweat-glands has been reckoned to be about two and a half million, representing a total length of tubing (each gland is a corkscrew tube) of twenty to thirty miles—long enough to reach half-way from London to Brighton!"

In hot weather and hard work there is a risk

of the temperature of the body rising too high, and one of the automatic ways of preventing this is sweating. The evaporation of the sweat lowers the temperature of the blood when there is a risk of it rising too high. Most mammals are thoroughly warm-blooded, which means more than the word suggests. It means that they keep up an approximately constant body-temperature, day and night, year in year out. If it is very cold weather, the muscles receive orders from the brain to produce more heat. If it is very warm weather, the sweat-glands are commanded to pour out more water, and that brings down the body-temperature. This is the chief significance of sweating.

A life-saving device.—It is intelligible, then, why the amount of sweating increases on a very warm day, or in the course of very hard work which makes the wheels of the bodily engines hot. It is an automatically working life-saving device. The commands to the sweat-glands are carried by nerves which accompany the blood-vessels or are independent of them; and these nerves come from special centres in the spinal cord and in the brain itself. But the further question rises, How do the nerve-centres, in the spinal cord or in the medulla oblongata, become *alive to the fact* that sweating is due? In the main, the answer is that this happens automatically because overheated blood or unduly impure blood flows through the centre, and, so to speak, gives the news. The G.H.Q. cells of the nerve-centre are excited by the hot blood

or exhausted blood, and they are not slow to act!

No sweating in birds.—The critical reader will at once perceive a difficulty. Birds are warm-blooded as well as mammals; they keep the same body-temperature summer and winter, day and night; but birds do not sweat. They have almost no skin-glands. The answer to this difficulty is this: there are other ways besides sweating of adjusting the body-temperature in the heat of the day. If the creature keeps very quiet, the tendency to feverishness will be lessened; if the bird seeks the shade of the wood, that also will help; if the blood-vessels in the skin expand under orders from the appropriate nerve-centres, there will be more blood exposed on the surface and more opportunity for cooling down. Or, again, when we see a bird or a mammal panting in the heat, this means that it is increasing its breathing movements and driving an unusual quantity of blood through the lungs with their rapidly changed air. But the more blood there is in the tissue of the lungs, exposed to air often changed, the more cooling down there will be. But there is something more—namely, that birds have a system of air-sacs in connection with their lungs, and, although there are not many blood-vessels on their walls, there is a certain amount of "internal perspiration." The water steals off in the form of water vapour, and this also brings down the body-temperature.

It comes to this, that sweating is very important to many a mammal because it counteracts a

dangerous rise of body-temperature in warm weather or during strenuous exercise, but *it is not indispensable.* The same end can be secured in other ways, as the case of birds plainly shows. We may say this also in regard to some mammals that sweat very little, if at all. Thus there are no sweat-glands in the spiny ant-eater of Australia—a fact of some interest, because this is a very primitive mammal, an egg-layer indeed, and because it is very imperfectly warm-blooded. Its body-temperature changes in an extraordinary way, and perhaps one might say that the creature would be more comfortable if it could sweat.

The dog is a good example of a highly-evolved mammal with comparatively few sweat-glands, and their relative scarcity makes the dog's panting more intelligible. It is cooling its blood in its lungs. But a feature in the familiar sight is the long tongue lolling out, and the meaning of this is not that the dog is sweating by its tongue, but that the evaporation of the salivary secretion from the surface of the tongue reduces the temperature in the adjacent blood, which tells a little on the general circulation.

Whales, cats, and sheep.—One book follows another in stating that sweating is absent in this or that mammal, but these statements must be subjected to critical examination. We are willing to believe that whales never sweat, but we are sure this is not true of the cat. The sweating horse is familiar, but the sheep is not far behind. In many cases there is particularly profuse perspiration on some special region of

the body, such as the palm of the hand and the sole of the foot in monkeys; and these are man's maximum areas for rapidly evaporating sweat.

As to our friends who assure us that *they* never perspire, we know that they are mistaken. They keep their skin in good condition; they take things easily and do not make hay when the sun shines; they wear loosely-fitting under-raiment; and their perspiration steals off as it is produced. It is what the physiologists call *insensible,* not *sensible,* perspiration. Such happy people have escaped from the penalty imposed on their first parents.

Cold sweat.—The "cold sweat" of anxiety and fear is interesting theoretically, for it shows that an emotional disturbance with its seat in the brain may influence the nerves going to the sweat-glands, so that the latter are provoked into unusual activity. Every plus in the body has its minus, and the useful *rôle* of the sweat-glands is taxed, so to speak, by the occurrence of the abnormal. Thus there may be too much sweat or too little, and worse things than either—especially when microbes, which penetrate so often into the bundle of life, appear on the scene and make themselves obnoxious. To the enthusiast for health the most important fact we have mentioned is that man has between twenty and thirty miles of skin tubes, for it is obviously very important that these should be kept open and in good order. We have read of tribes who have a sweat-house, half temple and half Turkish

bath, godliness and cleanliness being recognised correlates. It is a superheated vault where the braves swelter all night, issuing at dawn to plunge into the ice-cold river. That is the true spirit !

Chapter XI Hormones

THERE is undoubtedly a certain amount of competition among the different parts of the body, but the larger fact is their correlation. They seem to work into one another's hands, as if they had, in St. Paul's words, "a common concern for one another." This harmonious unification is in great part due to the nervous system, which has what one of the great neurologists calls an "integrative function." The central government is made aware of the needs of the outlying parts, and may supply these almost automatically, reflexly, as we say. More than that, the remote parts and the intricate recesses may be thrilled by or attuned to the purpose and feeling of the central government. "An artist to his finger-tips," we justly say. Another correlation is effected by means of the blood, that common medium from which every part derives sustenance and to which every part makes contributions. Now it is to the general idea of the blood as a correlating medium that there has been added in the last thirty years or so a recognition of the *rôle* of the ductless glands or "organs of internal secretion." Apart from anticipatory glimpses by Claude Bernard

and others, it is to Brown-Séquard that credit is due for first clearly discerning that a specific secretion may be contributed to the blood by a particular organ and distributed through the body with very effective results, especially in certain parts. The word "hormone," which means excitant, was invented by Mr. W. B. Hardy in connection with the remarkable discovery of "secretin" by Professors Bayliss and Starling in 1902. This substance, "secretin," is produced in the presence of acid by the cells lining the beginning of the small intestine; it is carried away by the blood-stream and it excites the pancreas or sweetbread to secrete its very important digestive juice which is poured into the food-canal. Thus, when a meal is in process, or it may be in prospect, there is by means of the excitant secretin a preparation for its digestion, and this illustrates what is meant by physiological co-ordination or correlation. For it is plain that the beginning of the intestine and the sweetbread work in one another's hands. Although the word hormone really means excitant or stirrer-up, a wider idea was from the first associated with it, namely, that of "chemical messenger"; as Sir Edward Schäfer points out, it might have been happier to have thought of the messenger of the gods and made the word not "hormone" but "hermone." But this is being wise after the event, and although there are hormones which inhibit instead of exciting, the word has come to stay. The internal secretion by which ductless glands and specialised patches of tissue produce hormones is conveniently

defined as follows by Professor Swale Vincent: "The process consists in the preparation and setting free of certain substances of physiological utility (the raw materials for which are supplied by the circulating blood) by certain cells of a glandular type; the substances set free are not passed out on to a free surface, but into the blood-stream." It is not too much to say that the discovery of the *rôle* of hormones has changed the whole face of physiology and has added incalculably to the biological control of life.

It may be that even in plants there are analogues of hormones, chemical messengers by which one part can influence another at a distance; and it may be that future discoveries (the inquiry is still young) will show that hormones are important in backboneless animals, where as yet we have only hints of their presence; the actual fact to-day is that it is only in regard to backboned animals that we are sure that hormones play an indispensable *rôle* in the internal economy of the body. It should be remembered that in backboned animals the blood comes to its own in a way that does not hold true for the lower reaches of the animal kingdom. The hormones in regard to which physiologists have securest knowledge are those produced by the thyroid gland, the parathyroids, the suprarenal bodies, the pituitary body, the mucous membrane of part of the digestive tract, certain islands of tissue in the sweetbread or pancreas, and the reproductive organs. It is obvious from this list that hormones are formed in very diverse parts of the body, and this sug-

gests the further fact that they have very varied properties. (1) Deficiency in the activity of the thyroid gland which lies on each side of our larynx spells arrest of development, cretinism, goitre, and the like; and everyone knows of the modern miracle by which these abnormal states are counteracted by giving the patients injections of the extract of the thyroid gland of sheep. An exaggeration of the activity of the thyroid leads to exophthalmic goitre and other disorders, for excess is as dangerous as deficiency. In a general way it may be said that the hormone of the thyroid seems to regulate the metabolism of the body, especially affecting the nutrition of connective and nervous tissues. It tends to keep the activity of nerve-cells up to the mark. (2) Of the smaller parathyroids, which are associated with the thyroid, it may be safe to say, although the hormone has not been isolated, that they put a brake on the excitability of nerve-cells. In other words, their internal secretion is, in Sir Edward Schäfer's terminology, a chalone rather than a hormone. But both would be included in Professor Starling's definition: "By the term 'hormone,' I understand any substance normally produced in the cells of some part of the body, and carried by the blood to distant parts, which it affects for the good of the organism as a whole." (3) The adrenalin produced by the medullary part of the suprarenal bodies (situated in front of each of the kidneys) is a very potent hormone, whose secretion is greatly increased by strong emotion, *e.g.* of fear or rage. It brings about a rapid

increase in blood pressure, it affects the distribution of the blood and the breathing movements, it increases the excitability of the skeletal muscles and their power of resisting fatigue, it increases the amount of sugar in the blood and its coagulability. It is easy to see that when the emotion of rage stimulates the flow of adrenalin, it thereby prepares the body for a fight in a somewhat detailed and very effective physiological fashion. Similarly, the useful effect of adrenalin in contracting the tiny muscles that erect the hairs of the skin is familiarly illustrated when a frightened or at any rate excited cat increases its size in facing up to a dog. Adrenalin is interesting in being the only true hormone which has been made artificially; yet how far it is from being a simple substance is suggested by its chemical name ortho-dioxyphenol-ethanol-methylamine, which surely means some labour of synthesis whether in the chemical laboratory or in the alchemy of the living cell. (4) Over-activity of the pituitary body, which projects from the under surface of the brain into a well protected bony cup about the size of a small hazel-nut, leads to the development of an unhealthy giant; pituitary insufficiency leads to an unhealthy dwarf, slow of pulse and weak in energy. Both of these extremes are to be distinguished entirely from healthy giants and dwarfs, who arise as freaks or mutations. But besides regulating growth, the pituitary body (especially in its posterior lobe) has to do with the storage and mobilisation of carbohydrates. We have said enough to illustrate the variety of

the functions which hormones discharge, and the impression would be heightened if we considered those produced by certain parts of the wall of the alimentary canal, that which is produced by peculiar islets in the pancreas, and has to do with carbohydrate metabolism, those proceeding from the reproductive organs which have to do with the development or non-development of secondary sex-characters, or with the preparation of the mother for the child both before and after birth. The complexity of the situation is increased by the fact that one organ of internal secretion may produce more than one hormone, and that there may be reciprocal interrelations between glands, so that they corroborate or counteract one another. It is difficult to answer the question: What, if anything, is the common characteristic of hormones? They vary greatly in chemical composition; they have specific effects, but except when a structural result ensues these effects do not last unless more hormone is produced; they are not ferments, yet they operate in minimal quantities. Perhaps their only common characteristic is the negative one, that they never evoke anti-bodies or counter-actives, as many substances do when introduced into the blood.

To the evolutionist there is much about hormones that is interesting. (*a*) One type of animal sometimes differs from another in the length of different areas on its life-curve, one having a long-drawn-out senescence, and another a telescoped juvenility; and we can see, as Professor Arthur Dendy points out, how this

might be fixed in the course of ages by variations in the activity of the ductless glands at different periods of life. (*b*) It has been shown that a strengthening of the musculature of the legs, *e.g.* in mountain-climbing or in dancing, may be correlated with an increase in the strength of the muscles of the arms. This probably means that some chemical messenger, exciting to the formation of muscle substance, is distributed throughout the system by the blood. And this, as has been suggested by Mr. J. T. Cunningham and others, opens up the possibility that specific hormones produced in the course of individual modifications by peculiarities of function and environment, might affect the reproductive elements in a representative manner, and thus likewise succeeding generations. (*c*) As to the evolution of the hormones themselves we cannot go far, but we must think of the body as a vast system of symbiotic organs, tissues, and cells. There is a continual "pooling" of products, and there has doubtless been an age-long elimination of those parts whose contributions tended to endanger harmony and stability. It is probable that some at least of the hormones are end-products or by-products of a routine of metabolism which had previously some less recondite significance, and it is noteworthy that some of the hormones are produced by structures (*e. g.* thyroid and pituitary) which have drifted from their primary utilisation. It may be as Professor Starling suggests, that these end-product or by-product hormones have been retained in the course of evolution not so much

because of any intrinsic philtre-like virtue in themselves, but rather because certain other structures happen to be peculiarly sensitive to their influence in the way of either spur or bridle.

Chapter XII *The Stones and Mortar of the House of Life*

THOUGH there were pioneers in Anatomy from Aristotle onwards, the old naturalists studied *the intact creature* more than its parts. Gradually, however, there grew up a science of *organs*, such as heart and lungs, brain and liver. At the beginning of the nineteenth century there was the beginning of the study of *tissues*—muscular and nervous, glandular and skeletal, and so on. With the improvement of the microscope came a deepening of analysis, and attention was focussed on the unit elements or *cells*. Finally, the inquiry has touched bottom in the investigation of *protoplasm*, which Huxley called "the physical basis of life."

Analysis of the body.—If we compare a body to a city, we begin our study with the external topography. Is it circular or square or crescentic or irregular? Then we look at the various regions of the city—the various quarters, whether municipal or manufacturing, educative or protective—the study of organs. But in many old towns there are streets of similar shops, like Paternoster Row and Fleet Street in old days, and these are tissues. But the individual shops and houses correspond to the various kinds

of cells. Finally, the elemental units of living matter may be compared to the inhabitants. If we are humble enough to let the comparison linger in our mind, we shall gain clearness in regard to the various levels of biological study, both anatomical and physiological, dealing with the organism, the organs, the tissues, the cells, and the protoplasm. There has been a logically deepening analysis, but investigation continues and must continue at all the five levels.

The cell-theory.—It was in 1838 that the cell-theory was first clearly formulated. It was rather a doctrine than a theory, for it stated the induction that all living creatures are built up of cells and modifications of cells, except indeed the simplest which remain unicellular. This is one of the foundation-stones of biology.

The corollaries were (*a*) that every ordinary multicellular creature, from sponge to man, from the sea-wrack to the cedar of Lebanon, usually begins its individual life as a single cell —a fertilised egg-cell, which divides and re-divides to form an embryo, which grows and differentiates to form a body; and (*b*) that the life of the multicellular organism is in some measure at least describable as the sum of the lives of the component cells, in the same way as the movements of an army are in some measure at least describable as the sum of the movements of the individual men.

Changes in cell-lore.—The advance of microscopical investigation has led to some interesting changes in cell-lore since the foundations were laid; and these deserve consideration. The

first noteworthy change is that the concept of the cell has become more subtle, and in some ways more elusive. On the old view, the cell was a unit-corpuscle or unit-area of living matter controlled by a nucleus. But this is too crisp to fit the facts. Many a cell is joined by living bridges to its neighbours; many a cell has no precise boundary; many a cell, like one of our red corpuscles, has, when fully formed, no demonstrable nucleus, but only, at the most, diffuse nuclear dust. We learned in our youth that the Protozoa are "single cells," but many of them are microscopic bundles of intricate minutiæ, and we feel sure that Prof. Clifford Dobell, one of the leaders in modern protistology, is right when he insists that they are to be regarded as non-cellular creatures, on a line of evolution different in idea from that of all multicellular animals. We also learned that egg-cells are single cells, but while this is true in a way, it is apt to lead to a false idea. For the egg-cell has a complexity beyond imagining; it is the heir of the ages; it is an implicit organism; it is an intricate inheritance; it is a creature telescoped down into a phase of being which we find it difficult to understand.

The colony idea.—Another modern change is that we no longer find it easy to think of the multicellular organism as a colony or as a regiment of cells. Perhaps this is not so very modern, for many years have passed since the great botanist, De Bary, wrote: "It is not so much that the cells make the plant; it is rather that the plant makes the cells." But it has

become clearer in recent years that the cellular structure is in part a device for the better working of that division of labour which the intricacy of vital processes demands. There is some truth, of course, in the colony idea, for we recall, for instance, that with the exception of thread-worms and lancelets, all multicellular animals, from sponge to man, have a body-guard of wandering amœboid cells (the phagocytes) which move actively from one part of the body to another, now serving as sappers and miners, and again as reconstructers, and again as en-gulfers of intruding microbes. There are many other instances of body-cells that retain a certain independence or autonomy. In some patho-logical processes, indeed, certain cells become anarchic and work the destruction of the organism to which they belong. But we have, at any rate, need to supplement the old colony idea with that of an organism whose specific living substance segregates for practical pur-poses into cells, just as a complex Protozoon, on the non-cellular line of organisation, has its specific substance segregated into miniature organs, organellæ.

The cell a microcosm.—Another change is that the modern picture of the cell has become extraordinarily complex. The old image of a little drop of living matter with a kernel, and sometimes with an enclosing wall, has become obsolete. We have to think of a more or less unified area of great chemical heterogeneity, a variety of colloidal protein substances suspended in a fluid along with other materials of less

complexity which are in part the reserve-products and the waste-products of living. In the centre of this whirlpool, with its diverse flotsam, there floats the nucleus, a little world in itself. Inside its membrane, through which materials are ever permeating out and in, there are the readily stainable chromosomes, usually definite in number for each species. Beside these, there is often a nucleolus, or there may be two or more nucleoli, and these are frequently of different kinds, for one nucleolus may be a "karyosome" of chromatin, and another a "plasmosome" of plastin; and bathing the chromosomes and the nucleoli there is a complex nuclear sap or karyolymph. But this is not nearly all. Outside the nucleus in the cell-substance or cytoplasm there are in many cells definitely formed granules or rods (mitochondria) which appear to have to do with the formation of particular protoplasmic products, and besides these there are the strands or rods of the "Golgi apparatus" which is a very frequent, if not a general constituent of cells. Of the significance of "Golgi's apparatus" we know almost nothing, and the same must be said of the "chromidia" which occur in many cells and are regarded by some authorities as migrations of chromatin from the nucleus, attempts, as it were, to colonise the cell-substance. This at least we are safe in saying, that the life of the cell depends in great part on give and take between the kernel and the cell-substance, the nucleus and the cytoplasm. In some cells the volumetric ratio between nucleus and cytoplasm appears to be

of great vital importance, and there are some cytologists who declare that the division of the cell is conditioned by strained relations between the two.

We were almost forgetting the tiny centrosomes which are constant in many, though by no means all, animal cells, but seem to be absent in higher plants. They play an important part in the division of the unit. When cell-division is about to occur, the centrosome, if present, divides into two; one takes up its position at each pole of the nucleus and becomes the centre of radiating threads of great delicacy, some of which are attached to the chromosomes. Each of these chromosomes in the majority of cases is split up the middle with meticulous precision, and as the two halves move towards opposite poles each daughter cell gets a very accurate half of the parent unit.

The germ-cells.—Another modern change of fundamental importance concerns the cytology of the germ-cells. It seems that the late Professor Weismann was right in regarding the chromosomes as the chief vehicles of the hereditary characters, although the cytoplasm (of the egg-cell in particular) certainly counts for something. A glimpse into the increasing precision of modern work may be got from the fact that in some cases it is possible to tell from visible peculiarities in the chromosomes of a fertilised egg whether it would have developed into a male or into a female. Not less striking is the fact that in a few cases it is possible to make a sort of map of a chromosome, and to

state with a high degree of probability that the factor for one particular character lies here and the factor for another character there.

It seems, indeed, that each chromosome is like a necklace of beads threaded on a transparent ribbon (of linin) and that the beads or microsomes are biological units of the lowest (visible) grade. In ordinary cases, as we have mentioned, each chromosome is split up the middle at each cell-division, and retains a certain individuality till the next division. But the individuality of the chromosomes is rather like the corporate individuality of a regiment, the really indivisible units being the beads or microsomes—which correspond to the men. Far from the cell being the biological unit, as used to be taught, it looks as if the unit was an inconceivably smaller thing—the microsome, unless, indeed, we react from this analysis to common sense and declare the biological unit to be the organism itself.

The cell-firm.—Our object in this study has been to give a glimpse of the intricacy that modern analysis has revealed in the structural elements that make up a multicellular body. But the result has been too static a picture. These elements are not like the stones and mortar of a house, they are *alive*. Each of them is comparable to a firm — cytoplasm, nucleus, centrosome, mitochondria, and so on, being the partners. And the success of the firm depends upon the way in which the various partners work into each other's hands in harmonious interrelationship. Each of the cells is a whirl-

pool of colloidal substances—proteins, fats, and carbohydrates. Each is a system organised for complex energy-transformations, for living matter does not create energy. Each is a laboratory in which there take place oxidations and reductions, hydrations (protoplasm containing 80 per cent. of water!) and condensations, synthetic and analytic processes. These chemical reactions take place with extraordinary speed, which is conditioned by the activity of ferments, and with not less extraordinary orderliness, which is conditioned in part by the localising effect of the very delicate framework of the cell, or what we might call the colloidal furnishings. It is evident that we are fearfully and wonderfully made.

Chanticleer is a polygynist, and he is not interested in his young family, but he is more than a little bit of a gentleman. How admirable his behaviour when he unearths some juicy grubs and summons his favourite or his whole harem to the feast. He looks away self-consciously, and seems to be admiring the scenery while his wives enjoy themselves. He seems to be saying, "You know it is against my principles to eat between meals."

There is a great difference in temperament between a cock and a hen. He is combative, passionate, courageous, somewhat patriarchal in his view of life. She is peaceful, timid, and eminently maternal. One must not of course judge the hen from the domesticated forms only, but from the ancestral Jungle-Fowl of India as well. For the wits of the hen have not been improved by living a sheltered life under man's care, and by being made the subject of a persistent artificial selection which has paid little heed to any qualities save producing a large number of eggs and being a good "table bird." Throughout its lifetime a Jungle hen will lay at the most forty to fifty eggs; but a

domesticated hen may lay three thousand! It has become an egg-laying machine, and that has not improved its wits.

There are, as everyone knows, four notable external differences between a cock and a hen. There are the exuberant, arched tail-feathers; there is the spur below the ankle; there are the loose and long, often very beautiful, hackle feathers on the neck; and there is the large, upright comb. Now there is a school of naturalists who hold tenaciously to the Lamarckian theory of the hereditary entailment of the results of use and disuse—an attractive theory if it could be based on facts and not on interpretations. As to the cock, these naturalists say that the fine bunch of tail-feathers is the outcome of generations of moving the tail about. When a feather is raised or otherwise energetically moved, this exercises the skin-moat or follicle in which the quill is imbedded, and this is supposed to stimulate the growth of the feather or of its successor. We should like to know more about the Japanese cocks with tail-feathers 10 ft. long, but, so far as we can discover, the Japs have kept their secret.

The theory goes on to interpret the cock's hackle feathers as the outcome of the way they are erected in the excitement of battle. And the spur is the long result of the doughty blows which fighting cocks deliver on the legs and head of their rivals. The Lamarckians believe strongly in the French proverb: "By force of smiting, one becomes a smith." As to the comb, why, it is the bird's response to having

a susceptible part often pecked! The reference is not to hen-pecking but to the frequent combats between rival cocks.

Personally, we cannot believe this is Nature's way. We prefer the Darwinian theory which postulates new departures (variations and mutations) arising from the germ-plasm, and being sifted in the struggles and endeavours of life. Those novelties tend to survive that are effective either in love-making or breadwinning. The hereditary cards are always being reshuffled, and the hand a player gets has often a strong "individuality," which may be advantageous or disadvantageous, but must in any case be tested.

Cocks and hens, ducks and drakes are familiar instances of the sex-dimorphism which is widespread in the animal kingdom, and finds very striking illustration among birds. There are three grades of it which may be usefully distinguished. First, there are cases where the male differs from the female in showing a more exuberant expression of characters which are shared by the female. That is to say, characters of the species are generously or extravagantly expressed in the cock, more restrainedly or soberly in the hen. Thus among poultry the cock and hen both have combs, but the cock's comb attains to a higher degree of development. The fleshy process on the forehead of the turkey cock is also represented in the female, but on a much smaller scale.

It is necessary to walk warily here, for we may have to do not with a specific character becoming a secondary sex-character but with a

secondary sex-character extending from the male to the female, and thus becoming a specific character.

The female reindeer is unique in having antlers, which in all other deer are confined to the stags. This looks like the extension of a masculine character to the female. There has probably come about some slight change in the female's constitution which allows of the expression of characters, in this case antlers, which normally remain latent. In birds the same sort of thing is probably taking place in many cases, *e.g.* in some of the pheasants (*Polyplectron*), where the females of different species show a graduated approach to the masculine splendour. Thus some of them show approximations to "eye-like" markings on certain feathers.

On a second grade may be ranked those birds where the male's peculiarity is as much qualitative as quantitative, where it is not merely a difference in exuberance but in the details of parts. The cock may have some specialised feature which is not hinted at in the hen. What we mean may be well illustrated by the Australian Lyre-birds. The males have sixteen tail-feathers; the outer pair are curved like a lyre, with very narrow outer and very broad inner web; the next six pairs have very distant barbs, and no barbules except towards the base; the two median plumes have narrow inner and no outer webs; they cross below and curve boldly outwards. Now this is obviously a tail with many peculiarities in form and structure; the female

has a long broad normal tail. There is an African nightjar, *Macrodipteryx macrodipterus*, in which the ninth primary feather on each wing of the male is greatly elongated to over two feet, which is more than twice the length of the bird's body. The shafts of these two feathers are naked except towards the tip, where they bear a racket-like expansion. There is no hint of this specialisation in the female. The male sits among the reeds and grasses, and the two long feathers are raised perpendicularly above his body. A very common feature, *e.g.* in Birds of Paradise, is the great elongation of two of the male's tail feathers, and it is easy to understand that exuberances are more permissible in the tail than in the wings, where the capacity for flight must not on any account be interfered with. There are some of the male Birds of Paradise that are said to look like golden fountains as they display themselves before the soberly coloured hens. The natives speak of the dancing parties among the branches.

Thirdly, there are those cases where the cock-bird possesses some feature which the hen does not show at all. Thus the domestic cock has a spur below the ankle which is absent from the normal hen. We must emphasise the word normal, for hens that have something wrong with their ovary, or have become aged, or have been operated on may develop a spur, and may take to crowing. Similarly, a capon has been known to brood and to lead out the young chickens, which is very far from an ordinary cock's way.

In the rare Great Bustard, which used to extend into Scotland, there is in the adult male an extraordinary throat pouch which opens beneath the tongue and descends into the neck. When the bird is excited and showing off in courtship he inflates the pouch, and this leads to an extraordinary swelling out of the whole throat region. There is no trace of this pouch in the female, nor can it be found in the young males.

Let us take a very different case, that of the extinct Solitaire of Rodriguez. It was a large bird, the male as big as a swan, the female smaller, and its relationships were apparently with the pigeons. The males were very combative, and their extraordinary peculiarity was the development of two large bony excrescences, about the size of walnuts, at the end of the radius bone of the fore-arm and at the wrist. They look like pathological bony excrescences, but they were probably of considerable use in fighting, and they are quite unrepresented in the females. There is an abundance of fossil bones, so that we can speak with certainty.

Now the probability is that all these exclusively masculine peculiarities arose as germinal variations or mutations in germs which were predestined to develop into male birds, and that they are, so to speak, harmonious or congruent with the male constitution. They are like seeds which will germinate only in "male soil." They must form a latent part of the female's inheritance, but they remain unexpressed. They may be called sex-linked characters, and

recent experimental work has shown that they are activated in the male by hormones from the reproductive organs, and inhibited in the female by some different kind of hormone from the ovary. When a duck is operated upon so as to remove the ovary, she afterwards puts on the complete plumage of the drake. This proves that the possibility of the drake's plumage is normally latent in the duck.

In many members of the duck family it is a peculiarity of the drake to have a large resonating sac developed in connection with the voice-box or syrinx. It is a masculine feature, but there is one kind of wigeon, an Australian species, *Mareca punctata*, the female of which is beginning to show the enlargement of the voice-box. This looks like the first step in the extension of a masculine character to the female as well.

What is the significance of all this dimorphism but to secure greater reproductive success, and to make the courtship a subtler affair, riveting psychical as well as physiological bonds? It is not necessary to suppose that the female in her so-called "choice" attends to every little detail of improvement in her suitor's get-up and behaviour. It may often be just the *tout ensemble* that arouses first her interest and then her excitement. It is not necessary that there be in every case the factor of preference, for those males will on the whole get on best whose constitution is instinct with virility, and that is what these exuberant decorations primarily express.

One of the large facts of life is individuality. Every living creature is itself and no other. A crystal of alum is identical with another crystal of alum, but it is quite different from a crystal of quartz; it is distinctive, but it has no individuality.

We do not mean that a hard-and-fast line can be drawn between non-living things without individuality and living creatures with individuality; but for practical purposes there is a significant difference. One star differs from another in glory, but there is *another kind of difference* between one rose and another, between one herring and another, between two dogs belonging to the same litter. Individuality is the peculiarity in the pattern of the individual's hereditary nature, and it may be accentuated by peculiarities in nurture. When dealing with the essential difference between two kinds of creatures, we may conveniently use the word *Specificity*. St. Paul was speaking of specificity when he said: "All flesh is not the same flesh, but there is one flesh of men and another of beasts, there is one flesh of birds and another of fishes." Individuality or idiosyncrasy is, as it were, specificity in miniature.

Bodily idiosyncrasies.—The word individuality is often used to denote a simple form of personality. It means that the creature is a self-contained unity. A corner of a sponge may be cut off without any damage. The sponge lives on unaffected; and the corner becomes a sponge. But we cannot play this kind of trick with a bird, where even a minute cut or lesion may be fatal. The bird is more of an individuality than a sponge is. In this sense an *individuality* means a unified integrate, and when there is a well-defined integration not only of the body, but of the mental or psychical life as well, we speak of a *personality*. Of this, again, there are many grades, culminating in man, whose personality excels that of any other created being, and often deserves a name of its own,—such as "soul."

But in this chapter the word individuality is used in a different sense, to sum up the peculiarities of an individual, which make it itself and no other. Why should one man's food, such as milk or eggs, be another man's poison? Why should two brothers often differ more markedly than two cousins? Why should a Loch Fyne herring (if there are any left) be very different from an East Coast herring? Why are we identifiable by our finger-prints? In short, why has each one of us his or her individuality?

Reason for individuality.—The hereditary relation between parents and offspring, between ancestors and descendants, secures a vital inertia and sustains a specific sameness from generation to generation. We do not gather grapes off thorns or figs off thistles. Like tends to beget like,

and the reason for this is found in what is called germinal continuity. But along with the tendency to persist there is the tendency to change, and this variability is one of the central secrets of life. Only in a dim way does any biologist understand the origin of the new, especially of the qualitatively new. But in the microscopic manœuvres which occur before, during, and immediately after the fertilisation of the egg-cell, there are opportunities—well known to biologists—for fresh permutations and combinations of the hereditary characters. An inheritance is like a hand of cards, and there is a shuffling of the pack at the beginning of each new life. Here we have the fundamental reason for individuality. It depends partly on the shuffling of the hereditary cards and partly on mysterious changes in the cards themselves.

Here we get the explanation, such as it is, of many familiar bodily idiosyncrasies—immunity to one disease and susceptibility to another; affectability by certain foods and drugs, and inborn perturbations in chemical routine which account for certain subtle and very hereditary constitutional diseases. All depend on peculiarities in the hereditary make-up.

In certain cases it may be that some minute item slips out of the inheritance, with the result, perhaps, that a particular ferment is absent in the adult, throwing some corner of the machinery out of gear. In other cases it looks as if the fault was with the regulatory system which harmonises many of the functions of the body. In other words, there may be excess or deficiency

or perturbation in the activity of those ductless glands whose accelerating hormones and slowing-down chalones regulate the general metabolism of the body so that its course runs smoothly (*see* chapter on " Hormones "). When the pendulum swings too far in one direction there may be a dwarf; when it swings too far in the opposite direction there may be a giant; and these are but diagrammatic examples of idiosyncrasies. Professor Garrod compares the ductless or endocrine glands to " a system of weights and pulleys, in stable equilibrium, in which removal of any one weight causes the whole system to hang awry."

Psychical Individuality.—What we are, after all, most familiar with is *psychical* individuality. Each man is himself, a particular pattern. This would be more obvious, both pleasantly and unpleasantly, were it not for coercive and deliberate repression. For this psychical individuality no one can propose to give a chemical formula; though, as we have hinted, the influence of the individual state of the endocrine glands is very strong. Our point, however, is just this, that the new departures, large or small, which make children psychically different from their parents, brothers from brothers, and cousins from cousins, are due to permutations and combinations in the implicit organisms or germ-cells from which these individuals develop. But we cannot explain mentality in terms of metabolism—that is jugglery; and it may be that the elusiveness of the problem of individuality or idiosyncrasy is due to the fact that the divergence is, from the start, not merely

chemical or metabolic, but likewise, *even in the germ-cell*, psychical or mental. Individuality is an outcome of Bio-Psychosis or Psycho-Biosis, as you will.

Peculiarities of reaction.—What we mean by specificity is that every clear-cut creature, worthy of a particular specific name, is itself and no other. Thus, in the life-history of the common liver-fluke, which causes the disease of liver-rot in sheep, the eggs that pass into pools of water on the damp pasture and develop there give rise to microscopic free-swimming larvæ, able to swim about with considerable rapidity by means of flexing and straightening lashes or cilia. In the course of their swimming they must come near or into contact with many different kinds of things, such as water plants, sticks, and stones, and various water-animals, but they answer-back to nothing save the proximity of a little water-snail. When they touch this mollusc (*Lymnaeus truncatulus* in Britain) they arrest their movements and they enter into the body of the animal, within which they pass through a succession of juvenile stages. Now the point is that the brainless microscopic larva responds effectively to no stimulus save the touch of the one creature through which it can manage to continue its life-history. There is no nervous system, only the potentiality (whatever that means) of one; so we dare not use any word like instinctive. In some way, difficult to define, the living matter of the cells of the larval liver-fluke is attuned to respond to the stimulus which means everything to the creature as a whole. They do not waste

energy in reacting to the futile. But one would like to know more definitely what this specificity of reaction means. It has its chemical analogues, *e.g.* in reactions which remain in suspense until a very minute trace of a catalyst pulls the trigger. But it is something subtler. It has its physical analogues, *e.g.* in "sympathetic resonators" which catch up only certain sound-waves out of the medley in the atmosphere. But it is something subtler. It is *vital* specificity.

Mussels and minnows.—The mother freshwater mussel produces its eggs early in the year, but it does not liberate them till the summer, by which time, within the cradle of the outer gill-plate, they have developed into pinhead-like larvæ with snapping shell valves and a capacity for producing glutinous (byssus) threads. It is a remarkable fact that the freshwater mussel's life-history cannot be continued unless a long chapter is passed on the skin or gills of a freshwater fish, such as minnow or stickleback or trout. In some North American freshwater mussels there is only one species of fish that will serve the purpose. Now, our present point is not merely that the mother mussel does not liberate its larvæ unless a suitable fish comes swimming by, but also that the minute larvæ are greatly excited by the vicinity of a suitable host. Even in the laboratory the larvæ are obviously stimulated when a little piece of stickleback is thrown into the aquarium in which they are resting. Their organisation, which is more complex than that of the larval liver-flukes, though still very simple, is attuned to answer-back to a particular kind of

stimulus which means everything to them. Their inheritance includes a remarkable differential sensitiveness.

Everyone knows how a butterfly or moth often lays its eggs on a food-plant which is suitable for the caterpillars, though of no nutritive significance to the full-grown insect. The mother ichneumon-fly chooses a caterpillar or the like in which it deposits its ova, and the victim is selected not in relation to any utility it has for the adult, but simply because it is well suited for the appetite of the larvæ. The pupal flea lies waiting within its case until man's footstep shakes the floor, whereupon it liberates itself with great celerity and jumps as if it had been jumping all its life. Some fly-larvæ in warm countries lie inactive in the earthen floor of the hut until the spot is warmed by the body of a human sleeper. There are hundreds of such cases of highly specialised sensitiveness, but they are perhaps more intelligible than those at lower levels. For the animals we have just mentioned have highly developed nervous systems, which doubtless include racial registrations, sometimes rising into hereditary capacities of instinctive behaviour.

Specific instincts.—True instincts should be contrasted with general innate tendencies like self-preservation and gregariousness, and with primary urges or appetites (hunger and love); for all true instincts (of which man has few) have a very particular reference. They are responses to precise stimuli, not to general situations. In other words, they are marked by speci-

ficity. The Yucca moth emerging one summer evening into an entirely new world flies to the Yucca flower, but not to other flowers; and it behaves in regard to the Yucca flower in one of two ways and in no other way. The great majority of instincts are quite precise. The nervous system has engrained answers-back which are activated by specific stimuli, and by these only.

Structural specificity.—It is surely a striking fact that the cells lining the windpipe of a horse are very different from those of similar function from the windpipe of a dog, and so in all cases. Each species is itself and no other. There is, indeed, great similarity in the blood of all back-boned animals, but no expert could hesitate for a moment in deciding whether certain blood-stains on the poacher's coat were due to bird, mammal, or man. Then there is the fact that the living bloods of nearly related mammals mingle harmoniously, whereas those of distantly related mammals mingle destructively. The flexible file or radula in the mouth of a wood-snail is at once distinguishable from that in the mouth of a garden-snail; everywhere we find "specificity"; each kind is itself and no other. The saying that "a bird is known by its feathers" is very literally true. We have seen a good ornithologist pledge his reputation for accurate identification on a single feather; and we have known a good ichthyologist who could identify any common British fish from a square inch of skin with its specific scales.

Chemical individuality.—Perhaps we are getting nearer the heart of the problem when we recog-

nise that every living creature has its own specific material organisation. There is a chemical basis to individuality, just as there is a more elusive psychical specificity. It is a matter of fact that the blood-crystals of a donkey are different from those of a horse; indeed those of a domestic dog are different from those of the wild or feral dingo of Australia. It looks as if every species had its chemical individuality, and this is not inconsistent with the Platonic view that each kind of animal expresses a unique idea. For the physical and the psychical, the metabolism and the mentality may be simply the two sides of the one shield of life. It was shown long ago by the French chemist, Gautier, that different varieties of grapes are dissimilar in their chemical composition, as if each kind had its characteristic chemical routine.

In pre-radium days we took the diverse chemical elements for granted, with vague speculations as to their possible evolution from some primitive kind of stuff out of which the fabric of the world has been spun. The Periodic Law pointed out, however, that the chemical elements might be arranged in series, which showed hints of affiliation among their members. Thus the third element on the third series showed obvious similarities to the third element on the second series, and so on. But the new theory of the chemical elements, which has been based on the investigations centred in the study of radio-activity, has made it certain that one element can be evolved from another, or, in other cases, legitimately thought of as evolved from another,

by the addition or separation of certain components. Lead is qualitatively very different from uranium; yet we can account quantitatively for the origin of the one from the other.

Now the species of animals and plants are very like chemical elements. Each is itself and no other. There is an extraordinary specificity. And yet, from the analogy of chemical elements, we can dimly see how big lifts might occur without there being anything magical or miraculous. Perhaps the change from one organic type to another, a brusque change which we call a mutation, is comparable to the change from uranium to lead. Perhaps the change from one variety to another, which we call a fluctuation or minor variation, is comparable to the change from one ethyl-compound to another.

Specific proteins.—In short, different species differ from one another in their dominant chemical compounds and in their prevalent chemical routine (or metabolism). All living matter includes as its most essential component a mixture of proteins, and the work of Emil Fischer and others "has revealed possibilities of almost infinite variety in the groupings and proportional representations of the twenty odd amino-acids and diamino-acids of which the protein molecules are built up." There must be a million million possibilities and more. "We may well believe that there are special proteins for every species, and indeed for every individual in a species."

This is the chemical basis of individuality. Every man his own laboratory. And in recognising this truth, we are not being committed to

the false simplicity of a materialistic view, since there is no warrant for supposing that the psychical aspect of a living creature is any less real than its physical or chemical aspect. Mentality is as real as metabolism. They are perhaps the two sides of a shield, the concave and the convex surfaces of a dome. Therefore when we speak of the chemical basis of individuality we need not imply that there is not a psychical basis as well. Perhaps, if we could rightly combine the fractions of reality that we know we should see the two bases as one.

One man's food, another man's poison.—Let us take another well-known instance of idiosyncrasy. Many of us know, or have heard, of people who become very ill if they eat even a small quantity of egg unawares. Sometimes a rash breaks out, sometimes an asthmatic attack comes on, sometimes there is colic, and other things occur. There are symptoms suggestive of poisoning. Very diverse animal food-stuffs bring about the same result—such as milk, mussels, and shrimps; but the sensitive subject, who is of course a rarity, is usually susceptible to one particular thing. Eggs make him violently ill, but milk will probably help to make him well.

A lady who was upset by a single prawn was quite unaffected by lobster or crayfish. The sensitiveness is very *specific*, and in genuine cases there is no influence of imagination, for the symptoms appear when the provocative substance was eaten by mistake along with something else. A man's life has sometimes been endangered by eating some soup or the like

which contained eggs too well disguised to be detected even by the tongue.

Hyper-sensitiveness.—An interesting point is that the "poisoning," let us call it, is rarely induced by vegetables or by fruits. There are some people, however, who cannot venture to eat strawberries, and in a case reported by Professor Pagniez the susceptible person could enjoy strawberries *provided they did not come from a particular locality!* Another important point is that the bad effects are not due to anything unwholesome in what is eaten. They are brought about by perfectly fresh and wholesome food, and must not be confused with the poisoning that sometimes follows eating mussels or shrimps that were past their best. The symptoms in the two sets of cases are quite different.

In the saying, "One man's food, another man's poison," there is perhaps some suggestion of the facts we have just referred to; but any approach to understanding them dates from the beginning of the twentieth century, and the first steps were due to the distinguished French physiologist, Professor Charles Richet. The interesting story of his discoveries may be outlined.

Sea-anemones and medicine.—Professor Richet tells us that during a cruise on the Prince of Monaco's yacht he was impressed by the virulent stinging powers of the strange marine colony known as the Portuguese Man-of-War, common in warm seas. A glycerine extract of its stinging threads was found to be extremely poisonous to ducks and rabbits into which it was injected.

He determined to study the matter further. But when he went back to France he could not obtain a supply of Portuguese Man-of-War, so he made a glycerine extract of the tentacles of sea-anemones (Actiniaria)—those common stinging animals that nestle like flowers in the niches of the seashore-pools. Along with M. Portier, who had been with him on the cruise, he injected the sea-anemone extract into dogs and found that it was very fatal. To some of the dogs which recovered, having received only a little poison, the experimenters gave, after three weeks, a second dose, and that a very minute one. They found to their surprise that the animals died in a few minutes. To the hyper-sensitive condition of the animal Richet applied the term *anaphylaxis*.

It was soon shown that the injected substance which brought on the hyper-sensitiveness when injected into an animal need not be a poison; it may be white-of-egg, or blood-serum, or milk, or muscle-extract, and so forth. The animal gets a good injection, and its blood answers-back, forming, it is believed, a counteractive or *anti-body*. After some time has elapsed (the "incubation period"), the animal receives a second dose, but a very minute one, which would not have any effect at all if the creature were not hyper-sensitive. Yet the result is a violent attack, often ending fatally. So to speak, the animal receives a hair of the dog that bit it, and that hair may kill. This is anaphylaxis.

Guinea-pigs and murder-trials.—Before we inquire into the physiology of anaphylaxis, let us

give some more examples. It is easy to make guinea-pigs hyper-sensitive to minute injections of different kinds of blood. After treatment A will answer-back to horse's blood, B to bullock's, C to sheep's, D to dog's, E to man's. Now, this affords a quick and certain way of deciding whether a small quantity of blood, even from a stain, is, let us say, a horse's or a man's. A solution of the blood is injected into the guinea-pigs A—E; if A reacts the blood-stain was equine, if E reacts the blood-stain was human. A strange rope to hang a man with!

Some guinea-pigs were subjected to injections of the muscle of a human mummy. After an interval they were tried with muscle-extracts from various animals, but they reacted only to human muscle, "thus proving, if proof were needed, that the chemical composition of the human body has not changed appreciably in the last three thousand years."

Hay-fever.—Some people suffer greatly from hay-fever, which is marked by "cold in the head," sore eyes, headache, and feverishness. In the majority of cases this is due to the inhalation of floating pollen grains from the air. In spring hay-fever the provocatives are usually the pollen grains of grasses; in autumn they usually come from other plants such as golden rod. But here we have to do with "an anaphylactic phenomenon," for the sufferer from what is a troublesome idiosyncrasy once had a bad infection and remains in a condition so susceptible, so hyper-sensitive, that a mere whiff of the

pollen-laden air suffices to bring on an attack of hay-fever.

If the irritation spreads to the windpipe and bronchial tubes the patient may become asthmatic. It may be mentioned that hay-fever can be induced in man and beast by injections of extract of grass pollen, and that there are now counteractive treatments which may save the patient from ever being troubled again. It seems a far cry from sea-anemones to hay-fever, but the logical chain is clear!

Primroses and poison-vines.—Some people, including professional gardeners, are extraordinarily sensitive to contact with a common cultivated primrose, *Primula obconica*, which looks innocence itself. After they have touched the plant a rash breaks out on their skin and there is great discomfort. This again is anaphylactic; a bad injection once, a persistent hyper-sensitiveness, and then a mere touch brings on an irritation quite out of proportion to the cause. The simplest remedy is to banish the obnoxious *obconica* and cultivate something else. In a deadlier way the same thing is illustrated by the poison-vine or poison-ivy of North America, sometimes planted in British gardens in mistake for a virginia creeper. It is one of the sumachs (*Rhus toxicodendron*), and contains a very poisonous oil, microscopic droplets of which must be carried off on dust-particles, for *susceptible* people are affected from some distance. It is plain that the old story of the upas tree has a grim basis of fact. And the poison-ivy does not stand alone.

A hair of the dog that bit you.—Dr. Markley reports a very curious case of a lady who was subject for years to a rash and eruptions on her face, neck, and fore-arm. All sorts of treatments were tried, including, as the author of *The Doctor's Dilemma* would be pleased to learn, the removal of the appendix. But all in vain. It was finally discovered that the irritation was due to contact with a guinea-pig which the lady's little boy kept as a pet. The application of a single hair was enough to provoke a reaction, but the hyper-sensitiveness was strictly local, being manifested only on those parts of the skin which had been previously affected.

Cases like the guinea-pig's hair, the primula, and the strawberry are somewhat of the nature of curiosities, and it must be understood that anaphylactic phenomena may be of great importance without being in any way picturesque. They may occasionally occur, for instance, in connection with drugs, such as quinine and antipyrine, or in connection with serum treatment. The hyper-sensitiveness or intolerance that develops in susceptible people is sometimes extraordinary. A mere whiff from a bottle of dry ricine may bring on violent symptoms, and a pharmaceutical chemist at a trial told the jury that he could not even open a bottle of ipecacuanha powder without weeping and sneezing.

A very interesting fact is that if the blood or blood-serum of an anaphylactic animal be injected into a normal individual the result is to induce anaphylaxis in the recipient, and this takes place

very rapidly. Moreover, an anaphylactic mother guinea-pig may have young ones which are born with her peculiarity—an evidence of the intimacy of the ante-natal partnership. But this congenital anaphylaxis does not last.

THE drowsy dog turns round and round, making itself comfortable in the imaginary herbage of the hearth-rug. What its wild ancestors did many thousand years ago it is doing to-night. The past is not dead—it is living still. And the horse that shies at a sudden movement in the hedgerow is reacting to the suggestion of a snake that bit its ancestor's heel. And does not the fond mother, in reproaching her boy for the wear and tear of his jacket in the course of arboreal excursions, call him "You little monkey"? That is proof positive; the past lingers and lives in the present.

Just as our masculine clothes show buttons without holes, and holes without buttons, obvious vestiges of old fashions, so our bodies are walking museums of relics, such as the little third eyelid in the inner upper corner of the eye, and the hardly usable muscles associated with the pinna or trumpet of the ear. In the body of a present-day organism the distant past still lives.

In a general way, and with many a short cut, the animal climbs up its own genealogical tree. It is easy to detect the fish in the life-history of the frog, and we have only to look at the gill-clefts on the neck of the embryo chick to be

convinced that it also had aquatic ancestors. The striking correspondence between the proportions of the salts in our blood and the proportions of the same salts in the sea is of itself enough to prove that the human race evolved from mammals, and these from reptiles, and these from amphibians, which sprang from fishes that lived in the Cambrian Sea.

There are endless examples of the living hand of the past, some almost dramatic, some sadly startling, as when we lose our grip and slip down several rungs on the steep ladder of evolution. But we are a little apt to focus too much attention on striking instances of the rehabilitation of the ancestral, for, when we think of it, the big and omnipresent fact is the continuity of life throughout the generations. In heredity we find the *universal* illustration of the hand of the past upon the present. Heredity is not a power nor a principle, nor any entity, but a name for the flesh-and-blood relation linking us to our forbears. Heredity is the genetic bond between successive generations, and it is such that, on the whole, like *must* beget like. The reason for this "must" was first made quite clear by Sir Francis Galton and August Weismann in their exposition of the continuity of the germ-plasm. When the fertilised egg-cell is dividing and re-dividing to form the body of the embryo, with its puzzling division of labour, a residue of germinal material is kept intact from body-building, and forms the beginning of the reproductive organs of the offspring, whence may be launched in due time another similar vessel on the adventurous voyage of life.

Like tends to beget like because the germ-cells are the descendants of unspecialised embryonic cells, which kept apart and did not share in body-making. They did not become specialised into nerve and muscle, blood and bone, but retained, like the ovum whence they sprang, the potentialities of all these. Instead of saying that the hen gives rise to the egg, we say that the egg gives rise to the hen *and* the eggs thereof. The great fact of germinal continuity has been often expounded. Galton compared the generations to pendants that fall off from the imperishable necklace of germ-cells. He said that there is a sense in which the child is as old as its parents. He called the parent the trustee of the germ-cells rather than the producer of the child. In a new sense, the child is a chip of the old block. Or as M. Bergson puts it in less static metaphor, " Life is like a current passing from germ to germ through the medium of a developed organism."

Heredity means the past living on—the entailment of a specific organisation; and the explanation of this is to be found in the fact of germinal continuity. We thus see *why* men do not gather grapes off thorns, or figs off thistles. We see *why* there is an inertia of type from generation to generation. Heredity is like the first Law of Motion. We see also why the dints suffered by individuals are not likely to be handed on; they do not specifically affect the germ-plasm.

What is clear on general grounds is familiar in experience—that all sorts of constitutional features, important and trivial, normal and abnormal,

mental and bodily, may be handed on from parent to offspring. There is no inborn peculiarity, save sterility, which may not be transmitted. Though "may be" is not the same as "must be," there is a fatalism in heredity which has been accentuated in modern times by the discovery of "unit characters," that is to say, clear-cut, crisply defined, non-blending characters, which are continued almost inexorably in at least some of the descendants, neither merging nor splitting up. A definite type of very intelligent dwarf has been known to reappear for four or five generations. The persistence of the Hapsburg lip is a well-known instance of a trivial unit-character that came and stayed. An abnormal peculiarity like having six fingers may defy dislodgment for six generations. When Charles the First was King of England physicians knew of the case of Jean Nougaret, who suffered from night-blindness, or inability to see in faint light. For more than two and a half centuries—we know of 2,000 individuals in ten generations—this night-blindness has cropped up in a certain number of cases, generation after generation. No normal member of the lineage has ever been the agent in handing on the peculiarity, which can scarcely be called a disease; the night-blindness has persisted through the abnormal members. Thus we get an impression of the inexorableness of heredity. What is bred in the bone and imbued in the blood is not easily got rid of. Consequences are unpitying. In the strict sense, the word "transmit" is not good; it suggests

the parent handing on something like a legacy. What happens is a *continuing on* of peculiarities in the specific organisation of the germ-plasm. To begin with, the heir and the inheritance are one and the same. In the strict sense, again, what continues on is not a "character," for a character is the *product* of hereditary "nature" and appropriate "nurture," to use Shakespeare's terms. For Prospero said of Caliban: "A devil, a born devil, on whose nature nurture will never stick." What are continued on in the germ-cell lineage are "factors," "determinants," or "genes," protoplasmic differentiations of some sort which are the vehicles of the primordia or initiatives of the various characters. And the factor for even a unit character often requires a particular kind of environment if it is to find expression. We are a little apt to mislead ourselves by forgetting the abstractness of our categories. A living organism cannot be thought of except as functioning in a particular environment. Development is the expression or actualising of the constituents that make up the inheritance, and this cashing and spending of the legacy demands a specific environment.

In the building up of an adult organism with a bodily and mental character of its own there are always three fates or factors. First and greatest is heredity, the flesh-and-blood linkage to parents and ancestors. Secondly there is environment, which includes all manner of surrounding influences, from food and sunshine to school and friends. Thirdly there is function—

our habits both positive and negative, our work and play, our exercise and rest, for not-doing moulds the body and mind as surely as doing. These are the three fates, but it is a mistake to think of them as separable except for scientific analysis and popular convenience.

The fundamental fact is the persistence of a specific organisation, which includes, in our case, not only general features such as vertebrate characters, mammal characters, and human characters, but more superficial and recent peculiarities of the race and the stock. When the organism is a viviparous mammal, there may be many peculiarities seen at birth which are not in the strict sense part of the inheritance. They are ante-natal modifications, due to peculiarities in the maternal nurture. Nor should we permit ourselves to mix up with the inheritance any dint or imprint which the individual may acquire as the result of peculiarities in function and environment. The possible transmission of these is a big question by itself. But the general outcome is that our inheritance, as in the immortal parable, consists of talents to which we cannot add, and from which we cannot take. The only thing we can do is to trade with them or, at the worst, put them out to usury.

The past lives on in the present, that is what is meant by heredity, and there is no gainsaying its fatalism. But the fatalistic aspect is far from being the whole truth. Thus there is an entailment of sturdy good qualities as well as of weaknesses; indeed, there is more staying power in

the integrative than in the disintegrative. There are few hereditary diseases. Secondly, while there is hereditary inertia and a tendency to complete hereditary resemblance, the genetic relation is such that a door is always open for new departures or variations. The germ-plasm is conservative, but it is also a fountain of change. Evolution is creative, and there is a continual emergence of the new. Thirdly, every item in the inheritance requires its appropriate nurture if it is to express itself fully. A hereditary "factor" is like a seed; it must have sunshine and rain and suitable soil if it is to develop aright. Now, this nurture is to a large extent within our control—from the cradle and before it to the school and after it—so that a deteriorative or reversionary bud may perhaps be kept sleeping, while a promising bud may be encouraged to unfold itself generously. This will help the individual, at any rate, and it will also help the race if there is an evolving nurture to meet and, as it were, welcome a new advance in hereditary nature. It is possible that improvements in function and environment may serve as the liberating stimuli of promiseful variations in the germ-plasm. Lastly, we must never forget that for man in a unique degree there is an external registration of the gains of the past. There is an extraorganismal entailment of progress, in institutions and tradition, in literature and art, and in the organisation of society itself. This counts for much in preventing man from slipping down the ladder of evolution, and in

prompting him to climb higher. Indeed, the importance of the social heritage is as supreme as that of the natural inheritance is fundamental, and thus Man transcends the trammels of protoplasm.

Chapter XVI The Influence of Habits and Surroundings

One of the most important of questions for mankind is: How much do peculiarities in habits and surroundings count for (*a*) as regards the individual, and (*b*) as regards the race? Everyone recognises that they leave their mark on the individual, but the limits of their influence are uncertain. The story goes that Dr. Joseph Bell, the famous Edinburgh surgeon, used to predict to his students the occupation and home of his patients—"Here is a shoemaker from Ayrshire," "Here is a blacksmith from Fife," and "Here is a granite-worker from Aberdeen." In any case there are dints due to occupation and environment which the experienced can read.

It is the same with plants and animals. The branching of the trees registers the direction of the prevailing wind; the state of the water-buttercup's leaves—whether slightly lobed or cut up into threads—tells us whether the plant was taken from a pond or a mill-lade. A plant taken from the low-ground to the mountain-side thickens its epidermis and increases the number of its hairs. Similarly, goldfishes kept in darkness for three years lose the rods and cones of their

retina and become blind. Water-snails which are not allowed sufficient room for exercise do not attain their full size. White rats which are forced to be very active for half a year show an increase of 20 per cent. in the weight of such organs as heart, liver and kidneys. There is no doubt as to the "modifications" which individual organisms may acquire as the direct result of peculiarities in function and environment.

Modifications or acquired characters are dints not outcomes, exogenous not endogenous, imprints from without not expressions from within. They may be defined as structural changes in the body of the organism, directly induced in the individual lifetime by peculiarities in function, nutrition and environment, which transcend the limits of organic elasticity, and thus persist after the peculiar conditions have ceased to operate. They are contrasted with germinal variations and mutations—the outcrops of new permutations and combinations in the germ-cells which develop into individuals.

There is no doubt as to the frequency of modifications. They often mean much to the individual; sometimes they are life-saving. In a few months a baby can be transformed from a bundle of bones to a plump and joyous cherub. By thyroid treatment a miracle of modification can be wrought on a cretinoid child; as the late Sir William Osler put it: "Within six weeks a poor feeble-minded, toad-like caricature of humanity may be restored to mental and bodily health." As modifications are common and often adaptive, it is not surprising that there arose, almost a

generation ago, an exaggerated expectation of what improved "nurture" might do for the human race. From this position there has been an almost violent reaction, for reasons which it is useful to consider. First there was the influence of the idea of germinal continuity. It is not so much that the hen produces the egg; it is rather that the fertilised egg-cell gives rise to the hen and the eggs thereof. Secondly, the evidence of the hereditary entailment of individual modifications turned out to be terribly anecdotal. Thirdly, it was discovered that many items in the inheritance are unit-characters—crisp, well-defined, non-blending, Mendelian—either there or not there. This applies not only to strange peculiarities like having fingers all thumbs (which may persist through at least six generations), but to ordinary features such as eye-colour. So an impression of the inertia of heredity has grown in strength, and many have swung to the conclusion that peculiarities in habits and surroundings cannot do more than impress individual modifications which never take racial root. It may be useful to show that this is not the whole story.

The first and plainest thing to say is that, if useful peculiarities directly due to peculiarities of nurture are not hereditarily entailed, it is more important than ever to see that they are reimpressed on each successive generation. This is the more important because a reimpressed modification may serve as a life-saving screen until, happily, an inborn variation in the same direction may arise. Nurtural tanning by the sun might

be a very useful modification until natural swarthiness appeared—if it did appear.

Secondly, although a modification be not entailed as such or in any representative degree, it may have indirect or collateral effects on the germ-cells—poisoning them, weakening them, perhaps strengthening them. If rats are subjected to frequent doses of alcohol, either by inhalation or in their food, the germ-cells are affected prejudicially. It may be that the unoxidised alcohol saturates through the body and affects the germ-cells along with the body. If specific substances formed under peculiar nurtural conditions lodge in the germ-cells, they may affect the development in a specific way as long as they last. Professor Agar's water-fleas acquired in peculiar conditions a bending-back of their shell-valves. After eggs had appeared and grown in the ovaries the modified individuals were transferred to normal water. The liberated eggs developed into forms *with reflexed valves* such as their parents had acquired. But when the parents laid again, the abnormal effect was seen only to a very slight degree; and in a third brood it had dwindled away. In all probability the peculiar nurture had resulted in the formation of some peculiar non-living metabolic product, some of which was included in the cytoplasm of the egg, passed thence into the body which developed from the egg, and there induced the same structural abnormality as it had originally evoked in the parent. This is, at least, a possible interpretation.

Hear the parable of the peach-trees which were

transplanted from Europe to Reunion. In the course of time they became evergreens, some in a few years, others in twenty. Now, some seeds of these modificational evergreens were sown in a mountainous region, and grew into evergreens. Was not this the entailment of an acquired modification? To answer this aright we must remember that the seed is not a germ-cell, but a young plant which has been living for a considerable time in close association with the parent. It is laden with chemical stuffs or metabolites made by the parent; and to these, perhaps, the evergreen characters of the sown peach-trees may have been due. Similarly, in a placental mammal a disturbance of the mother's chemical routine may in virtue of the intimate symbiosis affect the offspring congenitally, though not, in the strict sense, hereditarily. Thus a maternal production of butyric acid might mean, as Werber has shown, a monstrosity in the offspring. In mammals the effects of nurture begin to tell long before birth, and this has to be kept in mind when we try to discriminate in an individual, or a thousand individuals, between what is due to hereditary nature and what is due to environing nurture.

But there is another way in which functions and environment count for much. Every character in an adult is a product of the germinal "factors" and an appropriate nurture. As Professor T. H. Morgan says, and he is one of the leading Mendelian experimenters: "It is a commonplace that the environment is essential for the development of any trait, and that traits

may differ according to the environment in which they develop." The inheritance may be thought of as like a set of buds; they cannot be added to nor subtracted from after the egg is fertilised. But bad ones may be starved and remain asleep; good ones may be starved, so that a fine nature has an impoverished expression; good ones may be generously nourished and unfold with vigour. The Ethiopian cannot change his skin, yet improved nurture can work wonders in field and garden, in school and college. You cannot make a silk purse out of a sow's ear, but circumstances count. Mr. Beebe got his bobolinks to keep their breeding plumage through the year and sing their spring song at Christmas-time. And so those whom the gods love are often younger than their years.

The Red Chinese primrose, so familiar in greenhouses, has red flowers when it is reared at 15°–20° C.; but the same plant, reared at 30°–35° C., with moisture and shade, has pure white flowers. Tadpoles fed on minced thyroid show the usual differentiation, but remain dwarfs. But tadpoles fed on mixed thymus and spleen grow big without becoming complex—children who do not grow up. The wan newt called Proteus that lives in the dark streams of the Dalmatian caves has no pigment in its skin, and one might hastily conclude that the factor for pigmentation had slipped out of its inheritance. But this is far from being the case, and we should learn a lesson in caution. If Proteus is taken from the cave to a normally illumined aquarium, it shows a sensitiveness like a photographic plate;

it becomes first spotty and then dark. If it produces young in the new nurture, they are also dark, and the eyes which are very degenerate in the cave attain to a greater degree of development. Should we not be a little slower than we are in saying of some of our fellow-creatures—dwellers in darkness—that they have no this and no that? Perhaps, like Proteus, what they lack is the appropriate liberating stimulus, and this consideration lends fresh importance to the habits and surroundings of the individual.

It is a mistake to make an antithesis between obviously complementary factors. Is it the water or the wind that counts for most in making the waves along the shore? If two components are essential to a resultant, does it matter which we call the more important? There are, indeed, tough types, like Caliban; but the average organism is plastic within limits. That the individual is modifiable for better and for worse is an experimental certainty; the limits are undetermined. But whether this modifiability of the individual can specifically affect the race is another question—still to be left open.

Variability.—We have a great tendency to wonder at the wrong things. When a calf is born with two heads or a supernumerary pair of hind legs it gets a paragraph in the country newspaper. But the normal calf is more wonderful. We stare at the white blackbird or the tailless kitten, but we do not open our eyes to the little novelties which are continually emerging. There are doubtless some very conservative living creatures, some of which seem to have remained the same as regards their hard parts since their forbears were entombed in the rocks millions of years ago, but that is not the way with the majority. The living creature is a fountain of change. Like only *tends* to beget like. There is a strong tendency towards the persistence of a specific organisation (more or less perfect hereditary resemblance), but there is another strong tendency towards something new, whether a slight fluctuation or a more marked mutation (variability). Heredity is like the first law of motion; variability is like the second.

Examples of variations.—A microbe may suddenly change its nature; it is difficult to find two male ruffs alike; Lamarck's evening primrose seems to be making new species by the half

dozen. There suddenly appears a calf without horns or an ostrich with two extra feathers on its flightless wing. It is not difficult to find fifty different types of coloration among the eggs of guillemots, and young shore-crabs may be seen with at least a dozen kinds of livery. All the domestic pigeons are variants of the wild rock dove and all the cultivated cabbages are variants of the wild sea kale. Quite unexpectedly there appears in a family a perfectly healthy and very intelligent dwarf; in another household there is a musical genius; in a third a calculating boy. A copper beech, a greater celandine with cut-up or laciniate leaves, and a weeping willow may illustrate variability among plants; and apart from restrictions of space and time, one might give three hundred examples instead of three. An Angora rabbit, a waltzing mouse, a black peppered moth, a black sugar bird, a new pattern of potato-beetle or wasp, and a white rat may illustrate variability among animals; and apart from restrictions of space and time, one might give seven hundred examples instead of seven. Variability is a central fact of life.

Modifications.—In the preceding chapter we gave some examples of changes of structure which are wrought upon the individual body as the direct result of peculiarities in surroundings, food, and habits. When trout are placed in an aquarium with a white floor they soon become lighter in colour, but on a black floor they become darker. This is what is called a transitory individual *adjustment*, and it is due to the fact that the dark-coloured mobile pigment-cells of

the trout's skin are under the control of the central nervous system, which is susceptible to surrounding illumination : they contract or expand according to the light conditions. When trout are reared in an aquarium with a white floor they grow up with comparatively little black pigmentation, but on a black floor they grow up very sombre. This is what is called a lasting individual *modification.* If we could be sure that the offspring of the light-coloured trout would be light-coloured, when the floor of the aquarium is not white, or that the offspring of the sombre trout would be dark-coloured, when the floor of the aquarium is not black, that would indicate the transmission of modifications. *But we are not sure.*

Origin of the new.—If peculiarities hammered on to individuals are not handed on to the offspring, as such or in any representative degree, how do new departures arise at all? How do species " get out of the bit "? How can there be, how can there have been, any progress? This is a natural question, but in all probability it is missing the point of the origin of the new. It is thinking of the hen making changes in the egg or in the chick, whereas it seems more likely that the egg makes changes in the hen to which it gives rise. In other words, variations or new departures have a germinal origin; and it does not appear that they are representative of any " dints " that the parent may suffer, or of any gains that the parent may acquire by exercise or effort.

How, then, may novelties arise? The germ-

cell contains a large number of invisible representatives of the characters which will be expressed in the course of development. These are called " factors," " determiners " or " genes," and many of them (if not all) lie in the minute stainable rods or chromosomes of the kernel or nucleus of the egg-cell or sperm-cell. In the fruit-fly *Drosophila* there are known to be about 7,500 of them, and although they are invisible we know something about their topography in the microscopic microcosm of the germ-cell. Let us think of them as the cards in the inheritance pack. Variations arise through the shuffling of the cards. An important shuffling occurs when the germ-cells are ripening (maturation), for then the pack is always divided into two, and in the case of the egg-cell only half of the cards are used. Another important shuffling occurs when the egg-cell is fertilised by the sperm-cell at the normal beginning of each new life, for then two half-packs come together. Two complete inheritances—paternal and maternal—are mingled to form one.

Another possibility is that deeply saturating changes in the body—connected with changes in climate, food, use and disuse—may penetrate into the germ-cells and provoke new arrangements in their castle of cards. And just as we may sometimes see in a single-celled organism like the slipper-animalcule more or less spontaneous rearrangements and reorganisations of minute structure, so it may be that the germ-cells, which are single-celled implicit organisms, may have their more or less spontaneous rearrange-

ments and reorganisations, which lead to the emergence of something distinctively new. Perhaps the germ-cells make unconscious experiments in self-expression. This is the most difficult question in biology, and we can do little more than make guesses at truth.

Changes with a minus sign.—Many new departures are on the wrong side. They are disintegrative not integrative, degenerative not progressive. There are inborn constitutional idiosyncrasies serious enough in themselves to disturb body and mind profoundly; there are others which simply amount to a predisposition or liability to be disturbed by more or less extrinsic influences of a deleterious character. The trend of recent advances is to suggest that these inborn or germinal predispositions or susceptibilities may admit of chemical description.

It must be understood, however, that many of the disharmonies of the body cannot be described as ills our flesh is heir to. They are due to unhealthy surroundings, or to unwholesome habits and occupations, or to deficient nutrition (which is very different from having too little to eat), or to the poisoning influence of intruding microbes. The disturbing influence of the introduction of a little foreign pollen is well illustrated by the well-known hay-asthma, where the provocative cause of a vexatious malady is a contemptible sniff of wind-borne pollen.

Changes with a plus sign.—But we must not leave the subject without sounding the positive note. In all these discussions we are apt to

emphasise minus characters such as defects, taints, and diseases, the fact being that, for practical reasons, more scientific attention has been devoted to the seamy side of things. Happily, however, there are individual new departures on the plus side as well as on the minus. There is progressive as well as retrogressive variability. There is a continual emergence of human variants who, though not geniuses, represent a fresh point of view, a new mind-pattern. It is much to be desired that parents and teachers would recognise more vividly the incalculable promise of these novel idiosyncrasies when they are plainly on the upgrade. For it is in these promising idiosyncrasies that we discern the raw materials of progressive evolution.

Chapter XVIII Growth and its Ripple Marks

It is useful to think of the life-history of a living creature as an ascending curve. It begins in the fertilised egg-cell, in the majority of cases very much smaller than a pin's head. It is an implicit organism, a creature somehow telescoped down into a one-cell phase of being. This fertilised egg-cell divides and re-divides; it becomes a ball of cells, a sac of cells, and so forth; it shows division of labour or differentiation. That is to say, out of apparent simplicity there comes obvious complexity. Or in other words the embryonic creature, whether plant or animal, is expressing its inheritance, making the invisible visible, the potential actual. It is cashing its legacy, and we call this development. From the egg there emerges what may be a miniature of the future adult, or something very different —what is known as a larva, which must pass through a critical metamorphosis before it puts on full-grown characters. It goes on growing and eventually passes through adolescence to mature strength. After a while it passes down the slope of the curve, through ageing to death. The chapters of a life-history are many; we wish to say a little about *growth*.

One of the fundamental powers of the living

creature is growth. It means adding to the capital of the living body; it is capitalisation. It means lifting non-living materials into the charmed circle of the living. Organic growth is not like the growth of a crystal, for the crystal can grow only at the expense of material the same as itself. The crystal of alum grows in the solution of alum, but the grass grows at the expense of air, water, and salts; and the lamb grows, after its infancy, at the expense of the grass.

Nor does the living creature grow like a snowball rolled along the ground—by a process of external accretion. It incorporates the new material into itself in an active way. Moreover, the growth is regulated by the past, just as in the construction of a great building. What has gone before regulates what comes after. Once more, the growth of a living creature is rhythmic, rarely continuous. There is a spurt of growth and then a rest. There is rapid growth and then slow growth. Thus are produced what we venture to call the ripple marks of growth, which contribute not a little to the beauty of animate objects.

2,171 *years old.*—A delightful play for a child is to count the rings on the sawn stem of a tree. It gives an impression that lasts through life; line upon line, year after year, this tree had grown. And in the Museum there may be seen a section of one of the Big Trees of California, which have the distinction of having had a longer life than any other living creatures. There was one of them which showed 2,425 rings

when it was cut across, which meant that it had begun its life 525 years before the Christian era. Another one which stood nearly 300 ft. high was 2,171 years old.

Professor W. R. Dudley writes: "We have, deep in their annual rings, records which extend far beyond the beginnings of Anglo-Saxon peoples, beyond even the earliest struggles for liberty and democracy among the Greeks . . . records of forest conflagrations, of the vicissitudes of seasons, of periods of drought and periods of abundant and favouring rains."

Growth and the seasons.—The reason why it is possible to read the age of a tree from the rings on the cut stem is that there is a difference in character between the additions made to the wood in late summer or autumn and those that are made in spring. The late summer wood, formed in conditions of prosperity, has a large number of thick-walled wood-fibres with small cavities; the spring wood is marked by thin-walled wood-fibres with large cavities. The alternation of the two kinds of wood in the annual increment catches the eye and makes it possible to count the rings. Those who are expert in these matters can tell us something about the tree's life—*e.g.* that it took a hundred years to cover over with new tissue a big wound made during a forest fire.

Much attention has been given during the present century to the reading of the story that is recorded in the scales of fishes. Some scales are much more easily read than others, thus the salmon's are easier than the herring's;

but it seems generally true that a fish keeps a sort of diary in its scales. It may be noted that the scales of ordinary bony fishes are products of the under skin or dermis, and that they are covered over by a transparent, or partly coloured, epidermis which comes off on our finger and thumb like wet tissue-paper.

Ripple marks of growth.—A fish does not add to the number of its scales after its youth is past, but it adds to the size of each individual scale by the formation of successive zones of beautiful transparent cells, forming a substance that may be called "glassy ivory" (vitro-dentin). The additions that are made in the luxurious conditions of summer are different in quantity and quality from the additions made in winter, and the discontinuity makes it possible to read the age of the fish. Moreover, we can tell, just as in a tree, when there was a good growing year and when there was a severe one. Or in the case of the salmon, we can tell from a scale how many years the fish remained in fresh water before it grew restless and went down to the sea.

And similarly, how many years it remained feeding in the sea before it came up the river again, to the place of its birth, to spawn. The growth of the scale in the sea, where the salmon accumulate most of their living capital, is quite different from the growth in the river. And since the breeding, and especially the spawning, must involve a constitutional crisis, it is not surprising to find that it also is registered on the scales. From a microscopical examination of a

single scale we can tell whether the salmon has spawned, or is a virgin fish.

We can also tell whether it has spawned more than once. The study of the salmon is a great argument in favour of keeping (or not keeping) a diary. From the scales it has been found possible to clear up many obscurities in the successive chapters of the life-history. It may be noted, however, that it requires some apprenticeship before one can read the hieroglyphics correctly. Some bad mistakes have been made by people rushing in without the adequate preparation of patience and a trained eye. An interesting point is that the ear-stones or otoliths inside the ear of fishes show, when sectioned, a zoned structure which also records the successive years; and as some bones, like the vertebræ, often show rings of growth, there may be a corroboration of the age from two sources besides the scales. Out of the mouth of three witnesses the truth will be established. Not that there is any dubiety in a clear case like that of the salmon.

Line upon line.—Part of the beauty of shells lies in the concentric or parallel lines with which the surface is covered, and with these there is often associated a waxing and waning of colour that is very charming. In the shell of the freshwater mussel the more prominent lines indicate years, and the weaker lines between indicate minor periodicities. It may be noted that when additions to an organic structure take the form of line upon line, or platelet upon platelet, the result is often a physical structure of such a

nature that when the light falls upon it there is a rainbow-like appearance or iridescence.

The physical explanation is not always the same, nor is it altogether easy; but our present point is that regular increments of growth may give a surface a very fine physical coloration, as we see on mother-of-pearl or on a peacock's feather. There is no blue or green pigment in a peacock's feather, only a brownish one; but the fine sculpturing of the surface of the feather produces for physical reasons the beautiful brilliance; and the character of the surface is an expression of the way in which the feather grows. On a larger scale the cross-bars that make the feathers of hawks so pleasing seem to correspond to fluctuations—sometimes day and night fluctuations—of blood-pressure during the time when the feather was a-making.

Growth of a hair.—Some people show the effects of a crisis in some peculiarity in the growth of their finger-nails; and if you hold up a single hair against a strong light you will often see that its growth is punctuated. The general proposition is, that there are intrinsic reasons why growth should be periodic, not continuous, and there is external punctuation besides. Perhaps the deepest reason for the periodicity of growth is to be found in the fact that life consists of winding-up and running-down, loading and unloading, charging and exploding, up-building and down-breaking, anabolism and katabolism. But growth is a regulated affair, and part of its regulation is in the hands of hormones from the ductless glands, whose activities may be in

some degree periodic. As to the external punctuation, that depends on day and night, summer and winter, tides and meals, and much more besides.

The sea-urchin's spine.—The common sea-urchin of our shallow-water shore areas is a spherical animal the size of a large orange. It is densely covered with spines, and deserves its name of sea-hedgehog. The larger spines move on ball-and-socket joints and they help in the sea-urchin's locomotion. They grow gradually up to a particular limit, and it is known that if a sea-urchin gets them rubbed off in a trawl it can replace them by fresh growth. If a microscopic section through a spine be prepared, a very striking sight is seen. The section is like a tree-stem cut across. There is zoned structure of a very beautiful pattern, ring after ring of small cavities separated by beams.

The rings indicate growing periods; they are ripple marks of growth. They are not only very beautiful, though hidden away; they are architecturally sound. For they economise material and keep down weight without decreasing strength.

We have referred to the rings or lines on tree-stems, fish-scales, molluscan shells, and sea-urchins' spines, which all have this in common that they are ripple marks of growth. But it must be understood that there are scores of other good examples. It would be an interesting exercise to complete the score. In most animals there comes a stage when growing stops. Many

fishes and reptiles circumvent this punctuation and go on growing till they come to a violent end. But for most animals there is a definite limit of growth, after which there are no more ripples.

THE normal course of events for all ordinary living creatures is that the body ages—a subject to be afterwards discussed—becoming tired and weak. Then comes an environmental gust, nothing to what has often been weathered before, and the voyage is over. This is natural death, and although the cause may be entered in the books as "pneumonia" or something of the sort, the fact is that the body was more or less worn-out, particularly in some one hard-worked organ, such as the heart, the kidneys, the liver, or, less probably, the brain.

Diseases.—Sometimes, however, the life of the organism comes to an end before its time. Things go wrong. The ways of mice and men go oft agley, and disease sets in. Now disease simply means that there has been some serious perturbation of the normal chemical routine or metabolism. Disease is metabolism out of place, out of time, and out of tune. What is a disease in one creature may be normal in another; what is pathological at one time of life may be quite in keeping at another time. It must be understood, however, that we often include under the heading of disease what is actually the vigorous effort of

the organism to respond to an insinuating poison or to the attack of some intruder. In a fever the organism is doing its best to cope with a disturbance of the normal harmony.

Classification of diseases.—The biologist is apt to rush in where medical men fear to tread, and *vice versa*; but from the biological point of view diseases may be classified as (1) constitutional, (2) modificational, and (3) parasitic or microbic.

By *constitutional* diseases we mean derangements of normal metabolism which are due to some intrinsic or inborn defect, or weakness, or exaggeration—to some perturbation, in short, in the germ-cells. Some forms of diabetes and epilepsy are constitutional. It is of much importance to notice that constitutional diseases are almost unknown in Wild Nature. If they emerge, they are nipped in the bud.

By *modificational* diseases we mean derangements of normal metabolism which are due to something abnormal in surroundings, food, or activities. All man's occupational diseases are included under this head. Since wild animals are very intolerant of "unnatural" conditions of life, they show very little in the way of modificational diseases. Wild plants probably show more, since they cannot shift their quarters as most animals can. Domesticated animals and cultivated plants are of course very liable to modificational diseases, since man keeps them in unnatural conditions. Luckily, there is little or no hereditary transmission of modificational diseases as such, though the secondary results may prejudice the offspring. In this respect modificational dis-

eases differ markedly from constitutional diseases, which are often very heritable.

By *parasitic* or *microbic* diseases we mean the disturbances that are due to intruding parasites or microbes. Thus "liver-rot" in sheep and "ankylostomiasis" in man are due to the liver-fluke and the hook-worm respectively, and there are similar "worm" diseases in plants. It is convenient to keep the word microbe for the very minute single-celled parasites, like the bacteria causing plague and tubercle, or the virulent microscopic animals causing malaria and sleeping sickness. It should be noted that in Wild Nature the presence of numerous parasites often means little; a live-and-let-live balance has been established and very little damage need result. Thus the grouse harbours thousands of parasitic worms which are trivial, unless for some other reason the birds should become weakly. Then the parasites may multiply exceedingly and get the upper hand of their host. On the other hand, parasites usually run riot when they are transferred to some new host, which is constitutionally unaccustomed to deal with them, as when the tsetse fly infects man with the Trypanosome of sleeping sickness carried from the blood of some wild animal.

There is no hereditary transmission of microbic or parasitic diseases, for one organism could not form part of another organism's inheritance. But there may be infection before birth and there may be an hereditary continuance of a constitutional liability to the attack of a particular kind of microbe. As the normal course

of life is often brought to an abrupt end by the invasion of the body by parasites, and especially by parasitic microbes, we wish now to say a little about the general biology of infectious diseases.

Infectious diseases.—In some wild tribes it is the custom to expose disease-stricken children in the bush so that they may be devoured by wild beasts. This is done when the child sickens of certain diseases which the parents know they cannot cope with, even with all the help the medicine-man can give. It sounds terribly callous and we hold up our hands in horror. Yet we acquiesce in doings which are in the long run more cruel, as when we tolerate the multiplication of certain "types of humanity"—that is the authorised phrase—who are radically unsound.

Why do the natives we referred to expose their children who sicken of certain diseases? It is not that they do not care for them, for their mourning is obviously sincere. It is because they do not understand at all what the disease is, because they are powerless to do anything to help, and because they know from past experience that the disease "spreads." They also know that death comes quickly in the bush.

Now, we are apt to forget how young our own knowledge is in regard to infectious diseases. This year (1923) they have been celebrating Pasteur's centenary in France, and though he may not have been the first to link together microbes and disease, he was the first to prove the causal connection up to the hilt and to make the "germ theory" of disease current coin.

This theory, that certain diseases are due to the invasion of the body by certain microbes, was epoch-making in two ways. First, because it cleared the air, for it was a great step to know that a disease was not a mysterious monster stretching its hands out of the darkness and gripping man by the throat, but was due to a poisonous plant working from within instead of from without (like the poison-ivy), or was due to a beast of prey worrying from within instead of from without (like a wolf). Secondly, the theory was important because it suggested how the intrusion of disease-germs might be avoided or counteracted. As is usual in the history of science, a theoretical discovery was followed by practical applications; more light meant more control. It may be useful to consider very briefly some of the everyday ways in which certain infectious diseases may be avoided.

The microscopic minions of death.—It is understood, of course, that the microbes of disease are of extreme minuteness, that there may be a crowd of them on the point of a pin, or inside the letter "o" in this print. Most of them, like those causing tuberculosis, plague, cholera, diphtheria, and typhoid, are microscopic plants or bacteria. But some others of great importance, like those causing malaria, sleeping-sickness, and syphilis, are microscopic animals with complicated life-histories. An important general fact is that most of the microbes of disease are at home inside the living body and soon die outside; but this statement has to be supplemented by two saving clauses: first, that some

may live for a time in media like milk or water, and, second, that some have other hosts or victims besides man. Thus the malaria microbe is carried from man to man by the mosquito, and the bacillus of bubonic plague (or "the black death") is at home in the rat, and gets its first footing in man when he is bitten by an infected rat-flea. Later on, if the plague attacks man's lungs (becoming "pneumonic"), it may spread from man to man by the cough and in similar ways.

What do the microbes do?—It is easy to ask this reasonable question, but it takes a lot of answering. A few microbes find entrance into the body and in a few hours, it may be, the man is dead. The effect seems somehow out of proportion to the cause. "Behold how great a forest a little fire kindleth." Within the food-canal or in the blood, or in the windpipe and lungs, the invaders multiply with extreme rapidity. "A bacillus less than $\frac{1}{5000}$th of an inch in length multiplies, under normal conditions, at a rate that would cause the offspring of a single individual to fill the ocean to the depth of a mile in five days." Dr. Macfie calculates that the cholera bacillus can duplicate every twenty minutes, and might thus in one day have a progeny of 5 with twenty-seven noughts aft r it, and weighing over 7,000 tons! But before this happens the patient is dead!

It is not, however, by sheer multiplication that microbes kill, nor, in most cases, by making holes in tissues, blocking passages, or devouring blood-corpuscles.

These things may happen, but the main answer to our question, as far as bacteria are concerned, is that disease and death are due to poisoning. Many bacteria secrete albuminoid poisons or toxins which are fatal to various kinds of living cells within the body. In other cases the toxins are only set free by the destruction and solution of bacteria which is continually taking place. All that we can say in a few words is that the living matter of the body cells is disastrously susceptible to the presence of these strange albuminoids or proteins. It is remarkable that even an innocent stuff like white of egg may act as a virulent poison.

How the invaders enter.—Microbes may enter the skin by the moats or follicles at the roots of the hairs, and it is plain that the cleaner and fresher the skin is, the less likely are bacteria to settle and flourish. The mouth with its many crevices where microbes may lurk is a frequent area of infection, and in spite of various guards—*e.g.* in the nasal passage—the lungs are still more open to attack. They present an enormous moist surface of about ninety-seven square yards, and the covering membrane is very delicate. As regards the food canal there is rarely infection in the smooth-walled gullet through which the food passes quickly, or in the stomach with its acid secretion; but in the intestine, with its large, delicate, and irregular internal surface, opportunities abound. Here the microbes of cholera, dysentery, and typhoid fever find entrance.

It often happens that microbes enter by slight wounds in the skin, along with which must be

included the punctures due to the mosquitoes and tsetse flies, which introduce malaria and sleeping-sickness organisms respectively.

Professor Councilman says that the deaths of children from lockjaw following a Fourth of July celebration have often exceeded the total deaths in a Central American revolution. Lockjaw is due to the poisonous influence of the tetanus bacillus which is widely distributed in the soil and on the dirty hands of little boys. The toy-pistol wound means that a small piece of paper or metal is driven into the skin along with tetanus bacilli from the dirty surface. In a few days the microbes have multiplied and the terrible disease sets in.

How to avoid infection.—Sunlight is a powerful antagonist of disease-microbes, and those that float in dry, well-lighted spaces are mostly dead. It follows that we should do what we reasonably can to avoid dark lanes in a city and dark rooms in a house. In many ways light is a life-giver, but it is death to most bacteria, especially when combined with dryness. Perhaps it makes the microbes live so intensely that they die! More light is our first principle of safety.

The second is to be a little more fastidiously critical of what we eat and drink. There is no rotting without bacteria, and whenever food or drink has begun to go wrong we should be careful. It means that microbes are multiplying, and they may be producing what is poisonous. In many cases the danger is not in the bacteria that cause the rottenness, it is in what they are directly or indirectly producing. And they are

very likely to make the food more liable to be contaminated by other more virulent bacteria. Of course, one must exercise common sense. There are plenty of bacteria in butter-milk, but it is a very wholesome drink. There are plenty of bacteria in the most palatable cheese, but it is a very wholesome food. Yet there are good reasons for avoiding stagnant water, milk that has been standing uncovered, meat over which flies have been crawling, and mussels that have been too long out of the sea.

But the most important principle is to be fastidious in regard to other people, and this must be observed in moderation if one wishes to live a quiet life. What modern hygienic science has shown convincingly is that most of the disease germs pass from person to person by direct or indirect contact. There are "carriers" who are walking reservoirs of microbes and are continually infecting other people, sometimes by coughing and sneezing intemperately, sometimes by loud talking and laughing in which there is rain as well as wind, sometimes by kissing and fondling, sometimes by handling food and drink without proper precautions, sometimes by contaminating an article that some other person will afterwards use. One of the reasons why children are more liable than grown-up people to certain diseases must be found in their habit of putting things, including their own fingers, to their mouth. This is almost courting infection. And it must be remembered that besides "carriers" of typhoid and the like who have been very ill and have never got rid of the microbes, there are others

who have a disease so mildly that it is hardly recognised. These "carriers" are a menace to the community for they are reservoirs and disseminators of disease-germs. We must simply be as fastidious as we can.

It may seem a paradox, but it is a true saying, that the surest way to circumvent the dangers of infection is to be vigorously healthy. For in proportion to our healthfulness, *in many cases*, is the likelihood that the entrance of microbes will be baulked. They will meet with resistance on the part of vigorous tissues and blood that is better than blue. Of great importance, as Metchnikoff proved, is our bodyguard of wandering amœboid cells or phagocytes, which attack and destroy many intruding microbes. In higher animals they represent a particular kind of white blood-corpuscle, but they occur as wandering amœboid cells in many humble animals that have no blood at all. They may be said to be hungry for microbes and they are able to engulf and digest them. When the general health is good, the phagocytes are vigorous, and when there is an invasion of microbes the defence of the citadel is often effective.

Chapter XX   The Length of Life's Tether

All ordinary living creatures begin their individual life as fertilised egg-cells, that is to say, from the mingling of two inheritances, paternal and maternal. It is easy to find exceptions, like the drone-bees that have a mother but no father, or like the freshwater Hydra that usually multiplies by buds, or like weeping willows that are reproduced by cuttings, but the general statement holds good for the great majority: the individual life begins from the fertilisation of an egg-cell by a sperm-cell. What is true in the animal kingdom holds for most plants; and as high up as the Maiden's Hair Tree and its relatives, the male element is an active mobile cell, as in most animals, which seeks out the egg-cell.

In certain respects the history of a living creature shows compromise after compromise. The first compromises are between maternal and paternal contributions to the inheritance, and between what are called dominant and recessive hereditary factors. The offspring of a Black and a White Andalusian fowl is a Blue Andalusian. Then there is a compromise between the hereditary "nature" and the available "nurture," the first including all the potentialities or initia-

tives of the germ-cells, the latter including all manner of influences from surroundings, food, and habits. Then there is a compromise between "hunger" and "love," caring for self and caring for others. There is also the compromise between saving and spending, storing and exploding, winding up and running down—in technical language, anabolic and katabolic processes. Of great importance, too, is the compromise between the vital changes that tend towards ageing and those which tend to keep the creature young—the compromise between senescence and rejuvenescence. In illustration of this we wish to consider *the length of life* and the process of *growing old*.

It is difficult to make reliable statements in regard to the duration of life in wild animals. Even when a bird or mammal, marked in its youth, is shot after many years, we can only say that this species *may* live so long. For all we know, the average length of life may be longer or shorter. We can read the age of a salmon from the rings on its scales, but if we capture a fish showing eight yearly increments, that does not tell us the average length of a salmon's life, still less the maximum. But the accumulation of data from scale-reading will soon make precise statements possible.

Duration of life.—From records of captive animals we know that an elephant may live two hundred years, a golden eagle fifty, a toad forty, a crayfish twenty, a blackbird eighteen, and so on, but we must not assume that these figures will hold for the same animals living in a state

of nature. In some cases the captivity may shorten the normal length of life; in other cases the result may be increase. A parrot in captivity may become an octogenarian, but it is unlikely that this age is attained in the forest. But that was a good story of Humboldt's about an aged parrot that spoke the obsolete language of a tribe of American Indians for years after there was any human survivor able to understand it!

Guesses at truth.—There have been many attempts at hasty generalisation in regard to the ages of animals. There is an old saying that a wren lives three years, a dog three times as long as a wren, a horse three times as long as a dog, a man three times as long as a horse—that is, eighty-one years. We need not continue, for the next term in the series tells us that a donkey attains three times the age of a man.

There is a general impression that large animals, like elephants, live long, while small animals, like midges, have a short duration of life. There is, indeed, some truth here, for large size usually means considerable capitalisation of energy, and the possession of reserves will tend to prolong life. But the generalisation does not hold. A cat or a toad may live as long as a horse, say forty years; and a crayfish as long as a pig, say twenty years.

Another general idea was suggested by Flourens, that the length of life is always five times the period of growth; and here again there is a glimmer of truth. For a long-drawn-out growing period implies laying very firm foundations on which a secure adult life may be based. But the

generalisation does not work out. Thus a horse is mature in about four years, yet may live to be forty. The common eel usually takes five to eight years to become mature, yet it seems to die after its first spawning. After a long inclined plane of developing and growing there is often an abrupt downgrade to death.

Another idea that must be allowed to have some sense in it is that very active animals wear themselves out quickly, while easy-going creatures live long. Worker-bees in the summer-time usually die off in a few weeks, whereas a sea-anemone called " Grannie," which died an apparently natural death in Edinburgh on August 4th, 1887, was at least sixty-six years old. A Californian Sequoia or " Big Tree " has been known to live over two thousand years, while some insects live only for a few days. The unexcitable carp is said to live as long as the strenuous elephant, which many credit with two hundred years. Many sluggish animals, such as some of the molluscs, are far from being long-lived as compared with some of the intensely active birds. The fact is that while intensity of life means living dangerously, it need not mean a short life and a merry. Little is to be gained by contrasting types that are so remote from one another as shell-fish and tortoise.

Long-lived and short-lived animals.—We are confronted with an interesting puzzle: how it is that animal types, living somewhat similar lives, often differ greatly in average longevity. The solution is to be sought along two lines. In the first place, there are long-lived constitutions and

short-lived constitutions. The former are able to stave off the ageing or senescence to which all complex animals are liable; for the others this is not possible. But what are the ways of staving off senescence? The long-lived type of animal may have a highly efficient regulatory system which harmonises or orchestrates the bodily activities; and it may have great capacities for recuperation by means of long rests, perfect sleep, and frequent change of food and environment. And it must be remembered that reproduction is to some animals much more costly, in the physiological sense, than to others. This is important, for reproduction is often the beginning of death. The exquisite butterfly and the robust lamprey are alike in finding reproduction fatal.

Length of life an adaptation.—But the second part of the solution has to be sought by facing the question, Why animals that seem equally perfect in their physiological adjustments are nevertheless very different in longevity. The answer given by Professor Weismann, a quarter of a century ago, is that the length of an animal's life has been punctuated from without in relation to the particular conditions of its struggle for existence. Length of life is a constitutional quality, and it was probably, to begin with, very variable, as it still is, for instance, in men. Those variants which exhibited a tenure of life much too long or much too short to be suitable for the critical circumstances of each particular case would be eliminated. Those variants that had the most profitable length of life would soon lead

the race. The particular length of life exhibited by an animal has been determined by natural selection in the course of the struggle for existence. The punctuation is from without rather than from within.

The golden eagle, weighing 9 lb. to 12 lb., is intermediate as regards weight between hare and fox; all three are very strenuous; all three are intricate masterpieces. But while the hare lives ten years, and the fox fourteen, the golden eagle lives sixty. Weismann's interpretation is that the golden eagle secures its foothold in the struggle for existence because it has such a long life. It *must* live a long time, for it takes ten years to mature, and it only lays two eggs in the year. The two mammals are much more fertile than the bird, and there is less mortality among the young; so the fox and the hare do not require to live so long as the eagle. It is not for the welfare of the species that any organism should continue to reproduce after it is past its best—that is the one limit; but it is not for the welfare of the species that the population should dwindle greatly (when food is abundant and the area is not over-crowded)—this is the other limit. The length of an animal's life has been regulated in the course of time in reference to big issues—notably the rate of multiplication and the average mortality.

On growing old.—The most familiar imperfection of mankind is growing old. It is the almost universal disease which Huxley used to call "Anno Domini." There are indeed illustrious exceptions whom the gods love, who die young

though full of years; they are the progressive pioneer variants pointing to what may one day be a normal racial character. And of course there are those who do not grow old because they are carried off in their prime or in their youth by some accident or other, including a mosquito-bite as well as an explosion, poisonous food as well as shipwreck. But apart from these exceptions most of us grow old, and it is very inconvenient, especially when we grow old too soon. The human spirit rebels against it. "Growing old," said Stevenson to his friend, "that is a heresy to be fought against." But how far can it be fought against? What is its biological meaning? Is it inevitable? It is not for nought that we are ministers and interpreters of Nature. Can we not circumvent "Anno Domini"?

Immortal animals.—There are good reasons for believing that for most of the simplest animals there is no natural death. They may be killed, but they do not die. They have no complex "body" to keep up; they are able to meet their wear and tear by perfect recuperation; they grow young as fast as they grow old; and their way of multiplying by dividing is so inexpensive physiologically that immortality is not pawned for love. Barring accidents, they attain to bodily immortality. We are inclined to think that the same is true of some of the simple multicellular animals with bodies, such as the freshwater Hydra or the little living film called Planaria. It may be that they also have kept hold of bodily immortality.

Ageing a tax.—It seems that ageing is the tax on a body worth having. For a fine body means division of labour and complex "works"; it means laboratory furnishings as well as plenty of chemicals; it means not only the flowing river but the beds of sand and gravel which the stream lays down, which come to play an important part in determining its own course. But let us drop metaphor—if we can! The point is that a body worth having must include a good deal in the way of stable framework—beginning with the intra-cellular strands that circumscribe different areas in the colloidal protoplasm (and allow various witches' cauldrons to continue boiling on the same fire—metaphor again, alas!), and ending with substantial furniture like gristle and bone. Here we touch earth. From careful studies like Professor Child's *Senescence and Rejuvenescence*, it appears that what grows old is not the living matter, but the furnishings of the laboratory. Just because these are so stable, like the precipitates in the stream, they cannot be perfectly recuperated as regards their necessary wear and tear. It is not the living matter that grows old, it is the framework which it makes. As in all art, the living creature is limited by the possibilities of its material. This is a biological axiom. The "Big Tree" of California may live through two millennia, but it *must* eventually grow old. Theoretically, we can think of an immortal body, and this may have been achieved by polyp and planarian. But, for practical purposes, the statement holds, that in spite of many ingenious

processes of rejuvenescence, often very drastic, the processes of senescence get the upper hand, and the creature has to grow old.

Theories of ageing.—Metchnikoff laid emphasis on man's imperfect adjustment to his civilised environment. His organic evolution has not kept pace with his development of the arts of life. His thirty feet of food-canal are far too many for days of punctual meals and carefully prepared food. So there is warfare in the body and mutiny, some cells trying to destroy others that are better than themselves. They are helped to succeed by poisons released by bacteria in the food-canal, for these reduce the cell-resistance. And so Metchnikoff introduced the Bulgarian bacillus of soured milk to check the poison-making bacteria, and be, as he said, a "fountain of youth." But this theory cannot be the whole story, for senescence occurs among wild animals—though it seems almost never to pass into senility, which is practically confined to man and domestic animals.

In considering the duration of life we have referred to Weismann's theory, that the length of life's tether has been determined for each kind of creature by ages of natural selection. It is not for the good of the species that effete individuals should linger too long and probably beget an enfeebled progeny. So those variants that died off at the proper time led the species into safety. This also has its truth; the length of life is adaptive. But Weismann did not show why senescence is individually all but inevitable,

except in so far as the reason follows as a corollary from his doctrine of the immortality of the Protozoa, which are so simple in their constitution that there is perfect recuperation from the wear and tear of life.

Why do we grow old?—There are other theories of growing old, *e.g.* that poisonous waste-products accumulate, like ashes that put the fire out; that the ratio of nuclear-substance to cell-substance gets disturbed; that cells lose their power of dividing and beginning afresh, the nerve-cells of our brain losing this at birth; or that reproduction is physiologically expensive; that the endocrine glands get tired of making hormones or vitalising chemical messengers. But these theories seem to fasten on the *symptoms*, and miss the deep-rooted cause of senescence. The deep reason is that a body worth having is a very complex piece of organisation—we will *not* say machinery—and that the more stable parts which form the furniture of the laboratory cannot be perfectly kept in repair. Fatigue arrears gradually accumulate, especially in hard-worked organs like heart and liver, kidneys and brain. The organism gets into debt; natural death is the admission of insolvency. The practical problem is to try to secure an old age in which, to use Shakespeare's phrase, we do not "rot and rot," but only "ripe and ripe."

In his illuminating lecture on *Some Medical Aspects of Old Age* (1922) Sir Humphrey Rolleston says: "The cells of the complex organism depend for their duration of life not so much on an inborn

store of vitality as on metabolic changes in the colloids which in their turn are modified or controlled by extrinsic factors of various kinds." We venture to modify this deliverance just a little. We entirely disagree with Montaigne's dictum: "Man does not die; he kills himself"; and one reason justifies our disagreement, that senescence and natural death occur as normal phenomena in wild life. While we believe in the importance of deteriorative extrinsic factors in inducing *senility*, we cannot regard these as more than incidental for *senescence*. Ageing is a natural process—a defect of life's qualities—a limitation of its colloidal medium. It is due to the difficulty of perfectly repairing the furniture of the cellular laboratory, which we are quite willing to call the intracellular colloidal framework, if anyone thinks that description more scientific.

Our view is just this: simple unicellular animals have their times of cellular "depression," the details of which are well known; but, being very simple, they recuperate and start on a new lease of life. They grow old for a biological moment, and then they are young again! Rejuvenescence has an easy victory over senescence. Perhaps there is likewise a victory, but slower, in the case of simple polyps and planarians. In ordinary animal organisms, with bodies worth having, with terrific wear and tear of explosive metabolism and reconstruction-metabolism, there are indeed continual processes of rejuvenescence, yet senescence always wins—and, *must* win, worse luck! But the problem is—how to postpone the

victory. *It is well to think about "growing old"; it is better to think about "growing young."*

In Wild Nature there may be indications of senescence or normal ageing, but there is no senility. Most wild animals die a violent death in their prime. Why should man have a monopoly of senility? (1) Because of the artificial shelter of defective constitutions in accordance with the *just* demands of social sentiment—*just* as long as they do not encourage the hereditary continuance of pathological types. (2) Because of hereditary handicaps, some people being born old. (3) Because of the nature of the physiological bad debts, in the accumulation of which we too readily acquiesce. (4) Because man has very little resting instinct. (5) Because the rejuvenescence-changes which animals illustrate are only to a slight extent open to man. But perhaps they are more open than we think.

Man cannot indulge in the extraordinary internal "spring-cleanings" of the body by which some animals secure the continuance of youth, but he can insist more firmly on holidays and change, and thus avoid what Shakespeare calls "life-harming heaviness." Man cannot secure the long rests—it may be for half the year—by which some animals counteract the consequences of fatigue; but he can cultivate the resting habit more than he does. Man cannot surrender a damaged part as so many animals are able to do, to the saving of their life; but there are other things that can be given up besides parts. Perhaps

a good deal of premature ageing is due to neglect of the well-springs of natural joy, for "a merry heart is the life of the flesh." Perhaps, to be quite frank, the truth is that we require to be "born again" a good many times.

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